EVERYDAY SCIENCE WITH PROJECTS

SNYDER

THE CLIMAX OF SCIENTIFIC ACHIEVEMENT—CONQUEST OF THE AIR

American air squadron over San Diego, California

EVERYDAY SCIENCE

BY

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LOS ANGELES

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PREFACE

Everyday Science was written primarily for eighth and ninth grade pupils who will never have any further training in science. The book, therefore, covers a wide field, and does not unduly emphasize any of the special sciences. The subject matter is chosen not for the purpose of appealing to any group of special science teachers, but rather with a view to making pupils as intelligent and useful citizens as possible.

The book is, first of all, both interesting and simple, and aims not only to furnish a fund of valuable scientific information, but also to arouse scientific curiosity and to encourage further study both in and out of school. It will inculcate scientific habits of thought, and will substitute the beginnings of knowledge and confidence for misapprehension and superstition.

The usefulness of science is brought out in innumerable applications of its principles to the household, the yard and garden, the farm, the city street, industries, and transportation. Good citizenship is fostered by the interesting treatment of such subjects as personal hygiene, community health and sanitation, reclamation of lowlands, irrigation, forestry, coastal navigation, canals, and inland waterways.

But the pupil's scientific studies are not hemmed in by the four walls of the home, by the garden fence, or even by the nation's boundaries. Breadth of vision, imagination, and reverence are cultivated by a knowledge of the earth as a planet, of the main outlines of its physical history, of

its neighbors in limitless space, and of the changeless laws that govern its relations with the heavenly bodies.

The pupil is never plunged into discussions that are beyond his depth. Long, intimate experience with young students has shown how futile it is to presume any background of scientific information on the part of eighth and ninth grade pupils. From the very beginning the book proceeds from the known to the unknown, from the more simple to the less simple. It may be taught in its entirety to immature pupils.

To make the various subjects more vivid and more interesting, practically every topic is illustrated either by a photograph or by a drawing or by both. The many experiments help to fix the principles and to inculcate scientific habits of thought.

The present edition contains sixty simple projects which will appeal to boys and girls, and which can easily be worked out without the use of expensive material.

Thanks are due to the many teachers, especially in Los Angeles, whose suggestions have helped to make the book both teachable and learnable.

JULY 4, 1919. W. H. S.

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The study of heat, air, oxygen, carbon dioxide, running water, freezing water, solutions, atmospheric moisture, evaporation, and condensation in previous chapters now enables the pupil to understand how the earth has been shaped and how its rocky surface was gradually pulverized into soil.

The chapter on the origin of soil is logically followed by a study of man's use and conservation of soils.

Since light is necessary to life, this chapter on light supplements the preceding chapter and prepares for the study of life in the next chapter.

MAPS AND ILLUSTRATIONS

EVERYDAY SCIENCE

CHAPTER I

THE OPEN SKY

Go forth under the open sky and list
To Nature's teachings. — BRYANT.

The Sun. — Our earth seems so large to us, when we think of the time required for a trip around it, that we measure smaller things by comparison with it. But the sun is so tremendous that the earth is little more than a dot compared with it. To make a trip by fast express from San Francisco to New York requires about four days, and the average rate of travel is about thirty miles an hour. If such a train could follow the line of the earth's equator at this steady rate, it could complete the circuit of the earth in a little less than thirty-five days. But if it were possible to make a similar trip around the surface of the sun, more than ten years would be required for the journey.

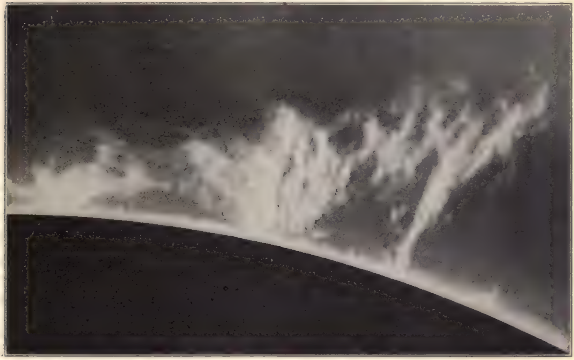
MT. WILSON SOLAR OBSERVATORY, THE 150-FOOT TOWER TELESCOPE
Probably the most effective instrument there is for studying the sun.

To get an idea of the relative sizes of the earth and sun, draw a circle an eighth of an inch in diameter to represent the earth and alongside of it a circle of a little more than thirteen and one-half inches in diameter to represent the sun. The diameter of the earth is about 8000 miles, and the diameter of the sun is approximately 866,000 miles. Imagine that the sun were hollow and that the earth could be placed at the center of this hollow sphere, with the moon just as far away from us as it now is — about 240,000 miles. The moon would also be inside the hollow sphere and almost as far away from its surface as from the earth. The sun is made up of more than 300,000 times as much matter as there is in the earth, and it occupies more than 1,300,000 times as much space.

Astronomers see the surface of the sun as a wild tumult of raging flame. The outside layers are made up wholly of incandescent gases; but the interior, because of the enormous pressure upon it, must be in a molten or solid condition. Stupendous eruptions and tempests of flame constantly rend its surface, causing incandescent gases to shoot up for hundreds of thousands of miles. Sometimes furious whirling storms of vast diameter occur. These often continue for long periods of time, and appear to observers on the earth as sun spots.

On account of the enormous amount of heat and light given out by the sun, it is well for us that the earth keeps at an average distance of about 93,000,000 miles from the sun. This distance is so great that we can have no adequate appreciation of it. If an express train which could travel the distance of the earth's circumference in about thirty-five days, could start off into space and travel day and night at the same steady speed in a straight line to the sun, it would require more than 350 years to reach its destination.

Of the total amount of heat radiated by the sun, the earth receives only about one two-billionth. Yet this tiny fraction of the sun's total heat furnishes practically all the energy of the earth. It has stored the earth's crust with coal, petroleum, and gas, from which we obtain heat, light, and power. It lifts the waters to the hills and covers the hills with verdure. It furnishes our food, the material for our



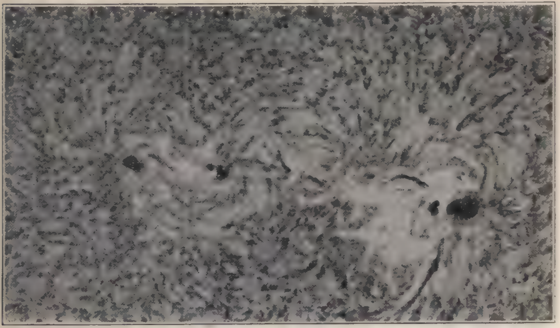
SURFACE EXPLOSIONS ON THE SUN

These gas flames shoot thousands of miles out from the surface of the sun. They were photographed during an eclipse.

clothing, and the very trees that shelter us from the midday sun.

The Evening Sky. — As the light of the sun fades in the evening, we see the stars coming out one by one until at last the sky is studded with them. We notice, too, that the brighter the star is, the sooner it appears. In the morning just the reverse of this takes place: the stars begin gradually to fade, and the brightest stars are the last to disappear.

We know how brilliant the light of a match appears in a dark room, and how a light of this kind seems to fade out when it is brought into the presence of a strong electric light. It would seem quite probable that the vast light of the sun might have the same effect upon the light of the stars. This supposition is also supported by the fact that when the sun is covered in an eclipse the stars begin to appear as in the



SUN SPOTS

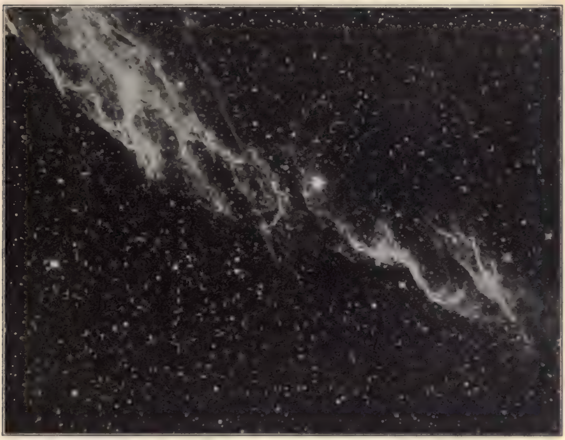
The furiously whirling areas shown in this picture are thousands of miles in diameter.

evening. Astronomers all agree that if it were not for the greater brilliancy of the sun we should see the heavens full of stars all the time.

If we carefully observe these myriads of bright points which dot the sky at night, we shall see that almost all of them shine with a twinkling light. There are, however, three of the brightest of them which give a steady light like that of the moon. When the positions of these three bodies are carefully observed for weeks or months, it will be

seen that they are continually changing their places among the stars, whereas the positions of the stars do not appear to change relatively to one another.

These bright, steady-shining points are called *planets*, from the Greek word meaning *wanderer*, and they belong to



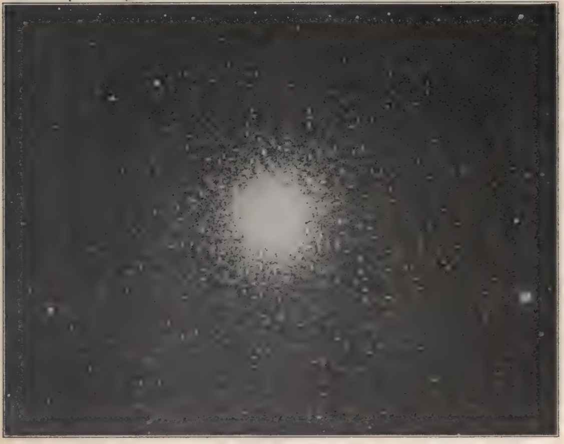
PART OF THE MILKY WAY

There are hundreds of millions of stars in the Milky Way, so thickly strewn that they appear to the eye as an irregular stream of light across the sky. The plate for this photograph was exposed ten hours and a quarter.

a family of heavenly bodies, of which the earth is one, that make regular circuits about the sun. This family of the sun is called the *solar system*. The planets are by far the nearest of all starlike bodies, although the earth's nearest neighbor, the planet Venus, never comes nearer than 23 millions of miles. The most distant planet, Neptune, is

2700 millions of miles farther away from the sun than the earth.

Each of the *twinkling points* in the heavens is a sun, shining by its own light. Our sun, if seen from the distance of one of the nearer stars, would appear like a twinkling star. Many of the distant stars are much larger than our sun.



A Star Cluster

This cluster appears as a single star to the eye.

There is reason to believe that some of them have their families of planets, and that our own solar system is only one of many similar systems that exist throughout space.

The distances to these suns are so great, however, that their brilliant lights appear little brighter in the evening sky than the flickers of so many candles. The nearest of these stars is probably about 25 thousand billion miles

away, or nearly 270,000 times as far away as the sun. This distance is so great that it takes light, which travels at the inconceivable rate of 186,000 miles in a second of time,

A CONTINUOUS PICTURE OF THE NORTHERN HEAVENS

The telescope was held pointed at the pole of the heavens for two hours and twenty minutes. The rotation of the earth caused the stars to appear as white lines, as if moving in circles.

over four and a half years to come to us from this nearest star.

From Arcturus, another of the stars, it takes light about 180 years to reach us. In other words, the light from Arc-

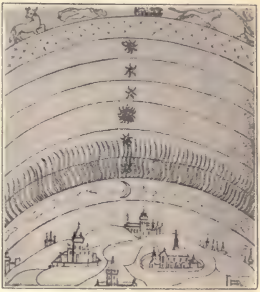
turus which reaches the eye to-night left that star more than thirty-five years before the battle of Lexington and has been traveling toward us ever since at the rate of about 16 billion miles a day. Other stars are so much farther away that it is impossible to measure their distances. No wonder the lights of the stars are so dim to us that they fade away at the brilliant rising of the morning sun.

Experiment 1. — Early on a clear evening when the stars are shining brightly locate the Big Dipper. (See page 10.) Carefully determine its position by standing in a definite place and sighting along the side of a high building or lofty tree. Make a sketch of the position of the Dipper and some of the stars near it. Several hours later in the evening stand in the same place and determine in a similar way the position. Make a sketch. Has the position of the Dipper changed in relation to your line of sight? What caused the change? Has its position changed in relation to the other stars? Locate some other constellations and make similar determinations.

All the stars appear to be fixed in their relative places. In the northern hemisphere the stars at the north appear to go around in a circle. The other stars appear to rise in the east and to set in the west just as the sun does. If we observe the stars that rise to the northeast, east, and southeast we shall find that they are above the horizon for different lengths of time.

The ancients noticed these facts and explained them by saying that the earth was at the center of a hollow sphere, upon the inner surface of which were the stars, and that this sphere was continually revolving about the earth, and also slightly changing its position with respect to the earth. We of the present day know that it is the earth that is turning on an imaginary axis and also gradually changing

its position in relation to the stars. The points on the surface of the earth through which this imaginary axis passes are called the *poles*. If this axis were extended far enough into space it would, at the present time, nearly strike a star in the center of the northern heavens which we call *Polaris*, or the North Star.



MEDIEVAL IDEA OF THE UNIVERSE

From a fourteenth century manuscript. Above the earth are the clouds and the moon; then the rays of the sun; next the various planets; above them the stars; and finally the signs of the zodiac.

Due to certain causes, the direction of the earth's axis slowly changes so that it has not always pointed so near to Polaris as it now does. A writer on astronomy reports having visited an observatory in China which was said to be 4000 years old. In it were placed originally two bronze eye-holes on a slanting granite wall for the purpose of sighting the pole star of that era. At the time of the astronomer's visit in 1874, the line of sight through these holes pointed to a starless area in the sky. Polaris has, however, been the guiding-star of mariners for a thousand years, and will remain so for thousands of years to come.

The Constellations. — Probably the first careful watchers of the sky were the shepherds of Asia. Just as we sometimes idly try to distinguish pictures in the glowing coals of a fire, so they by stretches of imagination grouped the stars into constellations that very roughly resembled animals

with which they were familiar. And so we have the constellations of the Great Bear, the Little Bear, the Great Dog, the Little Dog, the Bull, the Lion, the Eagle, etc.

The Greeks named other constellations after their heroes. It is disappointing to see how little these star-groups resemble the objects after which they are named, but we still retain the groupings and their names for convenience in locating individual stars. The Great Bear and the Little Bear — or, as they are more commonly called, the Big Dipper and the Little Dipper — are probably the best known of all the constellations because they are always in view in the northern heavens. The two stars on the edge of the Big Dipper away from the handle are called the pointers because they form a line that points toward the North Star. (Figure 1.)

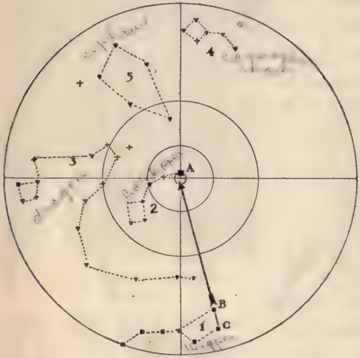


FIGURE 1. — CONSTELLATIONS IN THE NORTHERN SKY

A, Polaris, or North Star; 1, Big Dipper; *B* and *C*, pointers; 2, Little Dipper; 3, Dragon; 4, Cassiopeia's Chair; 5, Cepheus.

Our Solar Family. — We have seen that our mighty sun and its family of planets form but a tiny fraction of creation, and that our little earth is comparatively only a speck in the universe. Four of the eight planets that revolve

about the sun are larger than the earth, and two are nearer to the sun than the earth. (Figure 2.) The planets in the order of their distances from the sun are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. In the space between Mars and Jupiter there has been found a group of small bodies which are called *planetoids* or *asteroids*. The brightest of these is Vesta, which has a diameter of not more than 250 miles.

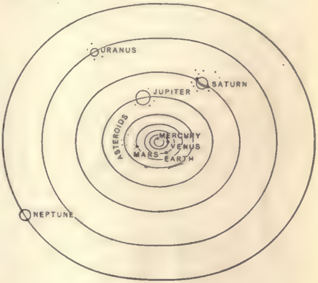


FIGURE 2. — DIAGRAM OF THE SOLAR SYSTEM

Showing roughly the positions of the various planets and their moons.

"Shooting-stars" (meteors) are small solid bodies flying rapidly through space. Sometimes they enter our atmosphere and become heated by friction while passing through it. Because they are thus heated they give off light. Sometimes they fall to the earth as *meteorites* but more frequently they simply pass through the upper part of the atmosphere. They are in no sense true stars.

Size and nearness to the sun are not the only respects in which the planets differ from each other. The surfaces of the planets Jupiter and Saturn, for example, are not solid like the surface of the earth. Saturn has ten moons to the earth's one. Venus and Mercury have none. The planet Mercury, nearest neighbor to the sun, must receive a withering heat; while the temperature of Neptune, the most distant planet, is probably colder than we can imagine.

The speed of the planets in their orbits and the length of their paths about the sun vary widely. Mercury travels through space about eight times as fast as Neptune, and completes its comparatively short trip around the sun in about 88 days. Neptune requires 164 years to traverse its vast orbit once.

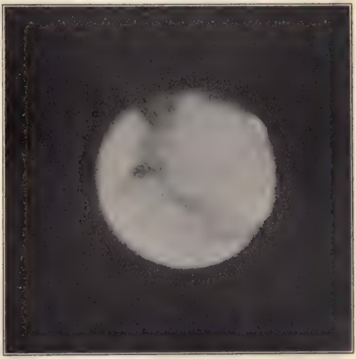
Astronomers have never satisfactorily determined what the length of day is on Mercury, Venus, Uranus, or Neptune—the two planets closest to the sun, and the two most distant. A day on Mars differs but little in length from the 24-hour day of the earth, but Jupiter and Saturn whirl completely around on their axes once in about every ten hours. The change of place of planets in their relations to each other and to the stars is owing to their respective motions about the sun.

A LARGE METEORITE

A "shooting-star" which fell to the earth.

The three planets which shine most brightly for us are Venus, Jupiter, and Mars. To the naked eye Venus is the most magnificent planet in the solar system, exceeding in light and beauty the brightest star. It is therefore called by the name of the Roman goddess of beauty. Jupiter,

the largest of the planets (317 times as heavy as the earth) takes its name from the king of the Roman gods. Mars shines with a reddish brown color, and on this account bears the name of the Roman god of war. Saturn is plainly visible at times, but the bright concentric rings, composed of little moonlike bodies that surround it and revolve about it, can be seen only with a telescope. When once in about every fifteen years Saturn is so situated that we have a view of the broad side of these rings, the telescope reveals what is probably the most beautiful sight in the solar system. Mercury is so close to the sun that it can be seen by the naked eye very rarely; Uranus can be singled out only by very sharp eyes; and Neptune is so far away that it cannot possibly be seen without the aid of a telescope.



MARS

Most like the earth of all the planets. It is supposed to have a polar ice cap. The noted astronomer Lowell argues that Mars may be inhabited.

The planets have no light of their own, as do the true stars, but the light which comes to us from them is a reflection of the light of the sun. When the astronomer turns his telescope on Neptune and its moons, he sees it by rays of light which, in making the trip from the sun to Neptune and, by reflection, back to the earth, have traveled five

THREE VIEWS OF SATURN

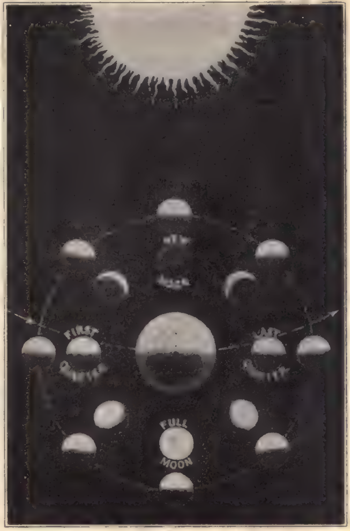
The planet with the beautiful rings.

and a half billion miles — the longest reflected rays of light known to man. If we could stand upon any one of the nearer planets, our earth, reflecting the rays of the sun, would also appear as a point of steady light in the heavens.

SURFACE OF THE MOON

Showing the great crater-like depressions.

The Moon. — We have learned that certain of the planets are accompanied by smaller bodies which are called *satellites* or *moons*. These moons revolve about their planets just as the planets revolve around the sun. Our own moon revolves around the earth at an average distance of about 240,000 miles and makes the circuit of its orbit in a little less than a month. Primitive people measured time by "moons." This is the origin of the word *month*.



PHASES OF THE MOON

Showing roughly the varying positions of the sun, moon, and earth.

The moon turns only once on its axis during a revolution around the earth, and so it always keeps the same side toward us. Its periods of daylight and darkness are, therefore, about 14 of our days long. The moon has a diameter of about 2000 miles and its weight is about one-eightieth of that of the earth. It has no air or water on its surface. Since it has not the leveling influence of wind and rain and freezing water, the surface is very jagged. It is covered with great craterlike

depressions, some of which are more than 100 miles in diameter.

Although we see the moon as a very bright object at night for a part of every month, yet it has no light of itself, and all the light it gives us is reflected from the sun. Astronomers tell us that we receive more heat and light from the sun in a quarter of a minute than from the moon in a whole year.

Total Eclipse of the Sun
From a photograph taken June 8, 1918.

As the earth goes around the sun and the moon around the earth, the position of these three in relation to each other is constantly changing. It is profitable to try to picture to oneself the changing phases of the moon. Study the diagram of the moon's phases, and see what the relative positions of the sun, earth, and moon are from the new moon to the dark of the moon.

It must sometimes happen that the moon comes directly between the earth and the sun. The moon is so much smaller than the earth, however, that it does not cut off the face of the sun from the whole surface of the earth, but merely from a comparatively narrow path. For hundreds of miles on each side of this path of *total eclipse of the sun,* observers see a *partial eclipse.* It is during a total eclipse that the pictures of eruptions of incandescent gases on the

sun's surface are taken. These form a *corona*, or crown of light, on the surface of the sun that surrounds the black outline of the moon. It must also happen at times that the earth comes between the moon and the face of the sun. If the earth's path lies directly between the two bodies, its shadow wholly obscures the face of the moon for a short time. This is called a *total eclipse of the moon.*

HALLEY'S COMET

One of the most famous visitors from outer space. The small white dots are stars seen through the comet's tail.

If it were not for the moon, the beauty and variety of our nights would be largely lacking. Moreover, as we shall see later, we should have no tides strong enough to help vessels over the bars into some of our harbors, and to sweep clean our bays, removing the sewage. If the distance of the moon were changed, the height of the tides would be changed, and this would greatly affect our coast towns.

Comets. — Sometimes comets appear in the sky and excite the greatest wonder. They usually have a very bright spot as the nucleus of a head, which shades gradually into a less luminous tail that streams across the sky for millions of miles. Some of the comets travel in great orbits around the sun and appear at regular intervals. They may be considered as part of the solar system. Others have appeared once and then have disappeared, never to return. Halley's comet is probably the best known of all the comets. It takes about 75 years to make a trip around its orbit and was last seen in 1910. It was named after the English astronomer Halley because, by mathematical calculations, he traced its history to almost the beginning of the Christian era, and prophesied correctly the year of its next return.

SUMMARY

The sun is more than 100 times greater than the earth in diameter and in circumference, and more than a million times greater in volume. It appears as a tremendous ball of flame, and is the source of the earth's heat and light.

The few steady-shining points of light in the evening sky which are constantly changing their positions among the stars are planets. These, like the earth, revolve in regular orbits about the sun as a center. Each of the myriads of twinkling stars is a sun, shining by its own light. There is reason to believe that many of these suns have planets revolving about them. The nearest of the stars is thousands of billions of miles away, and the distances of remote stars from the earth are immeasurable. The ancients thought that the earth was the center of the universe and that the heavenly bodies revolved about it, but we know that the

apparent motions of the stars are owing to the earth's movements on its axis and around the sun.

The ancients grouped the stars into constellations which vaguely represented animals or ancient heroes. Modern astronomers retain these groupings for convenience in studying the heavens.

The sun's family consists of eight planets and their satellites or moons, the asteroids, and occasional solar visitors called *comets*. The planets differ from each other in size, nearness to the sun, temperature, number of satellites, length of orbit, rate of speed, time of rotation, time of revolution, and in many other ways. They shine only by the reflected light of the sun.

All satellites revolve about the planets they accompany. Our own moon revolves about the earth at an average distance of 240,000 miles. It rotates once on its axis and travels once around the earth in a little less than a month. The moon's revolution about the earth accounts for its changing phases, for eclipses both of the sun and of the moon, and for our ocean tides.

Questions

What are the most impressive facts about the sun?

Why do we not see the stars in daytime?

How do the planets differ from stars?

Why are the lights of the stars so dim to us?

Do the stars appear to change their relative positions in the sky from time to time? What makes them appear to revolve around the earth?

In what respects do the planets differ from each other?

What are the most interesting facts about the moon? What accounts for its changes of appearance?

What causes an eclipse of the sun? Of the moon?

What is a meteorite? a comet? a constellation?

CHAPTER II

OUR OWN WORLD

The Development of Earth-Science. — From earliest times men have earnestly sought to increase their knowledge

THE WORLD ACCORDING TO HECATÆUS (500 B.C.)

about the earth. The ancient Assyrians and Babylonians early determined the definite directions which we call north,

east, south, and west; and carefully built the sides of their temples and palaces to correspond with these directions. The Egyptians developed the science of geometry (earth-measuring) primarily for the purpose of measuring land areas.

The great poet Homer shows that the Greeks of his time had made many careful observations of the earth's surface, as well as many ingenious guesses about it. He conceived the earth as a circular plane surrounded by the Ocean, a broad and deep river, which was the source of all waters. Homer's idea of the shape of the earth held sway for hundreds of years. As time went on, however, more and more was learned about the earth, until to-day a great amount of accurate knowledge has been acquired, which is of the utmost value to mankind.

FIGURE 3. — DIAGRAM SHOWING THE SHAPE OF THE EARTH

Any drawing which indicates to the eye the flattening at the poles and the bulging at the equator is of necessity tremendously exaggerated.

The Shape of the Earth. — Men who have in different ways made careful measurements of the shape of the earth tell us that it is an *oblate spheroid* (Figure 3); that is, a sphere which is somewhat flattened at two opposite points. An ordinary orange has this shape. The earth has been so little flattened, however, that its shape is very much nearer that of a perfect sphere than is that of an orange. Its polar diameter is only 27 miles shorter than its equatorial diameter; and so when we consider that each of its diameters is nearly 8000 miles, a shortening of only 27 miles in one of these would not change its shape from that of a sphere enough to be noticed except by the most careful measurements.

Experiment 2. — Attach a centrifugal hoop to a rotator apparatus and revolve. The hoop bulges at the center or point of greatest motion and flattens at the top and bottom or points of least motion. The earth revolves in a way similar to the hoop and is very slightly flattened at the poles.

Although some of the mountains of the earth rise above sea level to a height of over five miles, and there are depths in the sea which are somewhat greater than this below sea level, yet these distances are so little in comparison to the size of the earth that the surface is comparatively less irregular than that of an orange.

PARTIAL ECLIPSE OF THE MOON

Showing the curved outline of the earth's shadow.

In these days many men have sailed around the earth; but valiant indeed was that little company which in 1522 first proved that it was possible to sail continually in one direction and yet reach the home port, thus demonstrating that the earth was probably round. Long before, wise men had come to believe that the earth was a sphere, for it had been noted as far back as the time of Aristotle, the famous Greek philosopher, that when the shadow of the earth fell upon the moon, causing an eclipse of the moon, the boundaries of the shadow were curved lines. It was also later noticed that when ships are seen approaching at sea the masts appear first and then gradually the lower parts of the ship; and when ships sail away, the lower parts disappear first.

Experiment 3. — Add alcohol to water until a solution is obtained in which common lubricating oil will float at any depth. Insert with

a glass tube a large drop of oil below the surface of the solution. The oil will float in the solution in the shape of a sphere. This illustrates the fact that if a liquid is relieved from the action of outside forces, it will take the form of a perfect sphere.

A spherical surface is the smallest surface by which a solid can be bounded, and so the maximum distance which can separate places located on a given solid will be least when its surface is spherical. Thus the inhabitants of the earth, considering the surface over which they may scatter themselves, are brought into the closest possible relation to one another.

The Size of the Earth. — It is easy to say that the polar diameter of the earth is 7900 miles, its equatorial diameter

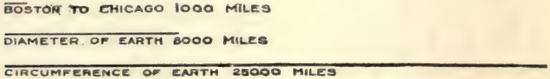


FIGURE 4. — LINES TO INDICATE COMPARATIVE DISTANCES

7927 miles, and its equatorial circumference 24,902 miles, but a true conception of these distances is not so easy.

Using as our standard any distance with which we are really acquainted, we shall find that the lines representing the different dimensions of the earth are very long. (Figure 4.) How vastly greater, then, must be the distances which were mentioned when treating of the sun and the stars!

The Earth's Rotation. — As has already been stated, the ancients considered the earth as the center of the universe and thought that the sun and stars revolved around it. We of the present day, however, know that it is the rotation of the earth from west to east that causes the appearance of the rising and setting sun and thus makes day and night.

Of course it makes no difference to the eye whether a light is brought toward the observer or the observer goes toward the light. We are turned into and out of the sunlight by the rotation of the earth. We speak of the sun as rising high in the sky, but what really happens is that we are turned so that the center of the earth, our heads, and the sun come nearer and nearer toward a straight line.

When we say *down* we mean toward the center of the earth, and when we say *up* we mean in the opposite direction. These are the only two directions that we could be easily sure of, if it were not for the rotation of the earth. This rotation gives the direction of the rising sun, which we call *east*, and of the setting, which we call *west*. A line which runs at right angles to the one joining east and west, *i.e.* one running parallel to the axis of the earth, is said to run *north* and *south*. Thus the points of the compass, as well as day and night, are determined for us by the earth's rotation. The north star, which is so important to the sailor in determining his direction, is simply a star which is almost in line with the axis of the earth.

The rotation of the earth gives us also our means of measuring time.

Days and Nights of Varying Length. — **Experiment 4.** — (A) In a darkened room place a globe a short distance from a small but strong light. Rotate the globe with its axis at right angles to the line which joins the centers of the globe and light. (Figure 5, A.) How much of the globe is illuminated by the light? Is the same part of the globe illuminated all the time? Does any place receive light for a longer time during a rotation than any other place? Remove the globe to the opposite side of the light without changing the direction of its axis. When rotated, is there any change in the globe's illumination?

(B) Now make the axis on which the globe rotates parallel to the line joining the centers of the globe and light. (Figure 5, B.) Rotate the globe. How much of the globe is illuminated by the light? Is the same part illuminated all the time? Does any place receive light for a longer time during a rotation than any other place on the globe? Remove the globe to the opposite side of the light without changing the direction of its axis. When the globe is rotated, is there any change in its illumination? If so, what?

(C) Place the globe so that its axis is inclined about 25 degrees from the perpendicular to the line joining the centers of the globe and light. (Figure 5, C.) Rotate the globe. How much of it is illuminated? Is the same part illuminated all the time? Do any places in the illuminated part receive light for a longer time during a rotation than other places? Remove the globe to the opposite side of the light without changing the direction of its axis. When the globe is rotated, is there any change in the length of time of illumination of the places before noted? If so, what?

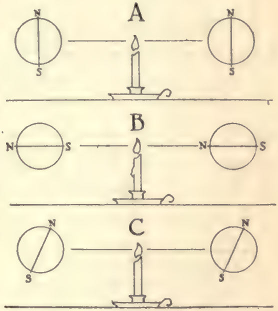


FIGURE 5.— RELATIVE POSITIONS OF GLOBE AND LIGHT

Corresponding to A, B, and C of Experiment 4.

As was seen in the previous experiment, the direction of the axis of a rotating globe has much to do with the light which different parts of it will receive from a luminous object.

When the axis of the revolving globe was at right angles to the line joining the globe and the light, no place on the surface of the globe received light for a longer time than any other place. This was not true when the axis was at any other angle.

As the axis of the earth is inclined to a line drawn from the earth to the sun, the light the earth receives is similar to that received by the globe in the last part of the experiment. Thus the days and nights vary in length during the year, because in summer the northern hemisphere is inclined toward the sun and in winter away from it.

The Movement of the Earth around the Sun. — The earth not only turns on its axis every day, but it travels around the sun, continually changing its position in relation to the stars. It moves with the tremendous average velocity of about 19 miles a second. It is this revolution around the sun which gives us our measure of time which we call a *year*. It takes 365 days and a fraction to complete this revolution; and so we consider 365 days to be a year, and add a day practically every fourth year to account for the fractions.

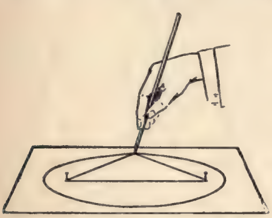


Figure 6. — Drawing an Ellipse

In the journey around the sun, the earth does not move in a circle but in an *ellipse*. To draw this figure, stick two pins into a piece of cardboard, a short distance apart. Place over the two pins a loop of string, and with the point of a pencil draw the loop taut as in Figure 6. If the loop is kept taut as the pencil point moves around the two pins, the resulting curve will be an ellipse.

The points where the pins pierce the cardboard are called the *foci*. Draw a straight line to join the foci, and extend the line to cut the ellipse at two points. Now place a small

object at one of the foci, and move another small object around the ellipse. The two objects will be closest together when the moving object reaches one of the two points where

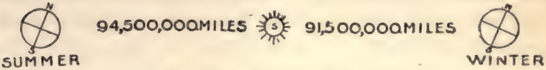


FIGURE 7. — THE EARTH'S VARIATION OF DISTANCE FROM THE SUN

the straight line cuts the curve, and farthest apart when it reaches the other point of intersection.

Now the sun is at one of the foci of the ellipse in which the earth moves, and so the distance between the sun and the earth varies during the year. This variation is about three millions of miles, the average distance of the earth from the sun being about 93,000,000 miles. Strange as it may seem, we are nearest the sun in January and farthest away in July. (Figure 7.)

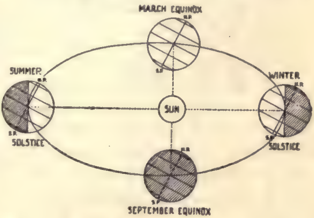


FIGURE 8. — THE PATH OF THE EARTH AROUND THE SUN

Showing roughly the four positions mentioned in the text.

The Cause of the Seasons. — Since the earth moves around the sun with its axis inclined $23\frac{1}{2}°$ from the perpendicular to the plane of its orbit, the northern and the southern hemisphere will at different times be inclined toward and away from the sun. (Figure 8.) In July the earth is farthest away from the sun, but the northern hemisphere is then pointed toward the sun, and the rays of heat from the sun fall more nearly vertically upon this hemisphere than during the rest

of the year. The more nearly vertical the rays, the greater the number that fall upon a given area, and the greater the amount of heat received by that area. In January we are closest to the sun, but its rays strike our hemisphere more aslant and therefore fewer heat rays fall upon a given area than in July.

Experiment 5. — Cut a hole 4 in. square in the center of a board 12 in. square. Fit tightly into this hole one end of a wooden tube 4 in. square and 1 ft. long. Paint the inside and outside of the tube a dull black. Hinge the opposite end of this tube 10 in. from the end of a baseboard 2 ft. long and 16 in. wide, having 6 in. of the board on either side of the tube. (Figure 9.)

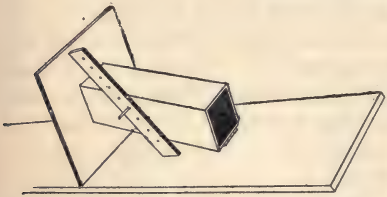


FIGURE 9. — APPARATUS FOR SHOWING THE HEATING EFFECTS OF SUN'S RAYS

On a clear day place this apparatus out of doors on a table freely exposed to the sun, with a piece of paper on the baseboard under the end of the tube. Point the tube directly at the sun in the early morning, in the middle of the forenoon, at noon, in the middle of the afternoon and about sunset. Mark on the paper the amount of surface illuminated by the sunlight passing through the tube at each of these different times. Why are different amounts of surface covered at these different times?

Place a thermometer in the centers of the surfaces covered by the sunlight passing through the tube at these different times. Note the different readings of the thermometer. Can you suggest a reason why they are not alike? The opening exposed to the rays has been the same throughout the experiment. Draw diagrams illustrating the action of the sun's rays in the different positions.

The number of rays of the sun which fall upon a given area depends upon the angle at which they strike the sur-

face. Figure 10 shows that the same number of rays fall upon a much smaller surface when the direction of the sun is vertical than when it is nearly horizontal. In the 30-degree arcs there are $2\frac{1}{2}$, 7, and $9\frac{1}{2}$ ray spaces respectively. The sun is here considered to be vertical at the equator, as it is on March 21, and September 23. Thus on these days, other conditions being the same, about one fourth

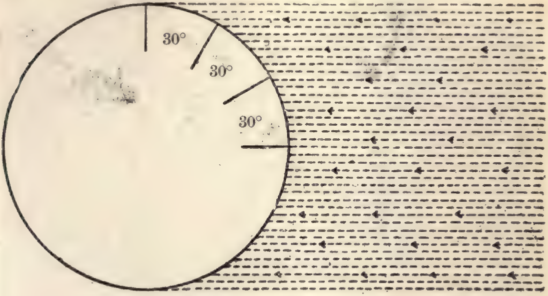


FIGURE 10. — HEATING EFFECTS OF SUN'S RAYS

Heating effects depend upon the angle at which the sun's rays strike the earth's surface.

as much heat from the sun falls upon the 30° about the pole as upon the 30° north of the equator.

When the northern hemisphere is inclined toward the sun, the rays of the sun cover the north pole continuously for six months, so that at this point there is no night for all that time. The days are longer and the nights shorter throughout all the northern hemisphere. More heat is, therefore, received in the northern hemisphere during these six months, not only because the rays of the sun fall more nearly vertically but also because the length of the day is increased.

The amount of heat received from the sun continues to increase as long as the sun appears to move north. The rays of the sun strike vertically the farthest point north on the 22d of June. This is called the *summer solstice.* At this time our days are the longest and our nights are the shortest. But the days are not the hottest, as the heat

A Hut in the Tropics

Having thin walls, but a heavy thatched roof to keep out the rain.

gradually accumulates for some time, more being received each day than is given off.

As the earth proceeds in its orbit from this point, the inclination of the north pole toward the sun becomes less and less, until on the 23d of September the sun is directly over the equator. The north pole now begins to point away from the sun. On December 22, the direct rays of the sun fall upon the farthest point south, our days being

then the shortest and the days in the southern hemisphere the longest. From this point until March 21, when the sun is again vertical over the equator, the inclination of the north pole away from the sun decreases. The days when the sun is over the equator are called the *autumnal* (Sept. 23) and *vernal* (March 21) *equinoxes,* since the days and nights are then of equal length all over the earth.

The greater heating of the hemisphere at one part of the year than at another gives us the changes which we call the *seasons.* Since the change in the length of the day and in the direction of the sun's rays is very small within the tropics, the change in the amount of heat received is very slight, so that in this region there is almost no change of seasons. But at the poles, where for six months there is continuous night and for six months continuous day, the change of seasons is exceedingly great. At middle latitudes the changes, though marked, are not excessive.

A LAPLANDER'S HUT

Made of thick sod to retain heat in the frigid zone.

There are then two causes which combine to give us our change of seasons: the revolution of the earth around the sun, and the inclination of the earth's axis to the plane of its orbit.

Meridians and Parallels of Latitude. — For purposes of measurement, circles of any size are divided into 360 equal parts called *degrees*. Thus the equatorial circle of the earth is divided into 360 parts. Through each of these divisions there is a semicircle drawn from pole to pole. These semicircles are called *meridians*. Each meridian is divided into 180 parts called *degrees of latitude*, and through these points of division are passed circles parallel to the equator. These circles gradually decrease in size from 25,000 miles at the equator to points at the poles. They are called *parallels of latitude* and are numbered from 0 at the equator to 90 at the poles. (Figure 11.)

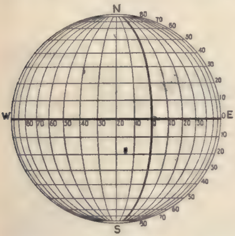


FIGURE 11. — MERIDIANS AND PARALLELS OF LATITUDE

A certain one of the meridians, usually the one passing through Greenwich, England, is called the *prime meridian* and numbered 0. East and west of this the meridians are numbered from 1 to 180. The degrees thus numbered are called *degrees of longitude*. Thus we have a skeleton outline by means of which we are easily able to locate the position of any place upon the earth. To secure greater accuracy than could be obtained by giving merely the degrees of latitude and longitude, each of these degrees is divided into 60 equal parts called *minutes*, and each minute can be divided into 60 parts called *seconds*.

The Measurement of Time. — **Experiment 6.** — On a fair day place a sundial in an exposed position, and after carefully adjusting it, compare its readings with those of an accurate watch. Unless you are on the time meridian, the readings are not alike.

Although the exact determination of time is a difficult task and requires great skill and very accurate instruments, yet it is not very hard to determine quite satisfactorily the length of a solar day. Before there were any clocks, people told the time of day by *sundial* (Figure 12), which consisted of a vertical " pointer " the shadow of which fell upon a horizontal plane. From local noon, or the time the sun cast the shortest shadow on a certain day, until it cast the shortest shadow the next day, was considered a day's time, or a *solar day*, and was divided into twenty-four equal parts called *hours*.

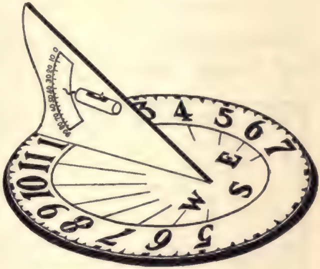


FIGURE 12. — A SUNDIAL

The direction of the shortest shadow is a north and south line, since the sun must then be halfway between the eastern and western horizon. As the lengths of these solar days vary slightly, for reasons which cannot be explained here, we now divide the mean length of the solar days for the year into twenty-four parts to get the hours.

The civil or conventional day begins at midnight, not noon. The determination of the exact time is very important; for the United States it is done at the Naval Observatories at Washington and at Mare Island, San Francisco, and telegraphed each day to different parts of the country.

Experiment 7. — On a day when there appear to be indications of settled fair weather place a table covered with blank paper in an open space where the sun can shine upon it. Make the top of the

table level and fix it firmly so that it cannot be moved. Fix vertically upon the table a knitting needle or a slender stick. Mark the line of the sun's shadow and note accurately the time the shadow falls on this line. On the next day note the time the shadow falls upon the same line. If your watch is right, the difference in time it shows between the falling of the shadows the first and the second day is the difference between this particular solar day and the *mean solar day*. This may be nearly a minute. The shortest shadow of the day marks noon. It extends north and south. (Your watch keeps mean solar time. But twelve o'clock by your watch will probably not be midday or high noon, as your watch is set to Standard Time.)

Standard Time. — When railways extending east and west became numerous in the United States and there

MAP SHOWING STANDARD TIME BELTS

were many through trains and numerous passengers, it became very inconvenient to use local time, since no two places had the same time. Each railway therefore adopted a time of its own, and when several railways entered the

same city, these different times became very confusing. Therefore in 1883 the American Railway Association persuaded the Government to adopt Standard Time.

A certain meridian was adopted as the time meridian for a definite belt of country. The meridians adopted were 75° for Eastern, 90° for Central, 105° for Mountain, 120° for Pacific Time. These meridians run through the centers of the time belts and for $7\frac{1}{2}°$ on either side the time used is the local time of the central meridian. When a person crosses from one belt to another he finds that the time makes an abrupt change of an hour. This system has been extended to all the United States possessions, and is coming into general use over a large part of the world. In actual practice the changes of time are not made where the boundaries of the time belts are crossed, but at important places near these.

International Date Line. — If a person should start at noon and travel around the earth from east to west as fast as the sun does, the sun would be overhead all the time and no solar day would pass for the traveler, even though 24 hours would be required for the trip. But when he reached home he would find that a calendar day had passed. This shows the necessity of having some generally accepted north and south line on the earth's circumference from which to reckon the beginning and the ending of a day.

Since the earth rotates once on its axis (the full 360 degrees of its circumference) in 24 hours, it turns in one hour $\frac{1}{24}$ of its circumference, or 15 degrees. Places on the earth's surface that are 15 degrees apart in an easterly-westerly line may, therefore, be regarded as an hour apart in time. Since the meridian of Greenwich is usually considered the 0 Meri-

dian, let us suppose it is high noon of Sunday at Greenwich. For every 15 degrees west of that point it will be an hour earlier, until at the 180th meridian it will be midnight of Saturday. For every 15 degrees east of Greenwich it will

MAP SHOWING INTERNATIONAL DATE LINE (Dotted line)

In the northern hemisphere, the Date Line varies from the 180th meridian so as to divide Asia from North America; in the southern hemisphere, so as to include certain English dependencies with Australia and New Zealand.

be an hour later, until at the 180th meridian it will be midnight of Sunday.

Thus, on one side of this line it would be Saturday midnight, and on the other side Sunday midnight. This represents the actual state of affairs. The 180th meridian, which

extends through the Pacific Ocean, is the accepted line which separates one day from the next. Thus any one traveling around the earth must drop a day from his calendar if crossing this line toward the west, and repeat a calendar day if crossing the line toward the east.

In practice, the International Date Line, where this arbitrary change of day occurs, does not quite coincide with the 180th meridian. A glance at the accompanying map will show why it is convenient to vary the Date Line from the meridian line.

Daylight Saving. — In midsummer the sun rises between 4 and 5 o'clock in middle latitudes. Thus it is well up in the heavens before the average citizen is astir. On the first of April, 1918, the United States Government decided to set the clock ahead one hour. This gave more daylight in the ordinary waking hours, and thus effected a saving in the cost of lighting. On the 27th of October, when the long days were past, the clock was set back one hour, and normal time was resumed. Many countries did this during the War.

Magnetism of the Earth. — There is a peculiar property of the earth which has been of the greatest assistance to geographical explorers and without which it would be very difficult to find a way over the sea. This property is called *terrestrial magnetism.* In very ancient times pieces of iron ore were found which had the property of attracting iron. Such pieces of ore are called *loadstones.* Artificial loadstones are called *magnets.*

Experiment 8. — Having pushed a long cambric needle through a small disk of cork so that it will float horizontally, carefully place the disk and needle upon the quiet surface of a large dish

of water. Does the needle assume any definite direction? Taking the needle from the water stroke one end of the needle from the cork out with the north end of a magnet and the opposite end with the south end of a magnet. When the needle is again floated on the water is it indifferent about the direction in which it points?

FIGURE 13.

The discovery that a bar of loadstone or a magnetic needle, if floated or freely suspended, will invariably assume a definite position was made in the Far East at a very early date, but it was put to no particular use in the sailing of ships until about the middle of the thirteenth century. Since then it has enabled sailors to go far out from the sight of land and yet always to know the direction in which they are going. It was supposed even up to the time of the first voyage of Columbus that the magnetic needle always pointed toward the north star or perhaps at some place a little to the east of it. The sailors of Columbus were greatly alarmed when they found as they sailed west that the needle swung off to the west of the true north.

REGION AROUND THE NORTH MAGNETIC POLE
The + marks the position of the pole.

This difference in the direction of the needle from a true north and south line is called the *declination*. The westward declination was one of the great discoveries of Colum-

bus. We know now that the reason for the declination of the needle is that the north end of it does not point toward the north geographical pole as was at first supposed, but toward a point in the southwestern part of Boothia Felix which is called the *north magnetic pole.* The south magnetic pole as recently determined is a little to the east of Victoria Land.

These magnetic poles do not remain in the same place all of the time but swing slowly back and forth, so that the declination changes for the same place. On account of this it is necessary for surveyors, who use the compass, to find out the declination each year. The annual change in the United States varies from 0 to 5 seconds.

SUMMARY

The ancients thought that the earth was flat; but modern scientists have proved in many ways that it is an oblate spheroid, slightly flattened at the poles and bulging at the equator — somewhat resembling an orange in shape. Its polar diameter is 7900 miles; its equatorial diameter is 7927 miles, and its equatorial circumference is 24,902 miles.

The rotation of the earth on its axis gives us our days, the points of the compass, and our means of measuring time.

The earth revolves about the sun once a year, not in a circular, but in an elliptical, orbit. Its average distance from the sun is 93,000,000 miles, but it is 3,000,000 miles closer to the sun in our winter than in our summer. Since the axis of the earth is inclined 23½ degrees from the perpendicular to the plane of its orbit, the northern hemisphere in summer is pointed toward the sun and in winter away from it. It is not closeness to the sun but directness of its ray that gives us our summer heat. The inclination of the earth

on its axis as it moves around the sun, therefore, accounts for our changing seasons. This inclination also accounts for the varying length of our days and nights.

We locate places on the earth's surface by means of imaginary circles drawn around the earth, which are called meridians and parallels of latitude. From the equator in either direction to the poles is a quarter of a circle or 90°. From a zero meridian we measure a half circle, or 180°, east, and 180° west.

From the time the sun casts the shortest shadow one day until it casts the shortest shadow the next is a solar day. Solar days differ slightly in length; and so, for convenience, a calendar day is the average of the solar days of the year. To avoid the endless confusion that would be caused by each community having its own local time, the United States is divided into belts 15° wide. Throughout one of these belts, standard time is the same, and each belt differs by one hour in time from a neighboring belt. The International Date Line (about the 180th meridian) is the line which for convenience marks the beginning and ending of a calendar day. Setting the clock ahead one hour during the summer months gives more daylight during working hours. This is called daylight saving.

The earth has a north and a south magnetic pole. These do not correspond with the poles of the earth's axis, nor do they remain stationary. The attraction of these poles for the magnetic needle or compass enables mariners always to determine direction.

Questions

What simple reasons are there for believing that the earth is round?

Draw circles illustrative of the size of the earth, moon, and sun.

What was discovered in the experiment with the globe and the light?

How have the movements of the earth around the sun, its rotation on its axis, and the direction of its axis, affected the conditions of your life?

Why do we have winter in the northern hemisphere when the earth is nearest the sun?

If a man should leave Cairo, Egypt, on June 21 and travel slowly to Cape Town, reaching there on Dec. 21, what changes of season would he experience?

How is the length of the day determined? If it were noon Thursday, Sept. 30, with you, what would be the day and date at Yokohama?

What are the advantages of Standard Time?

What are the reasons for the establishment of an International Date Line?

If it is twelve o'clock local time at your home, what time is it at Paris? At Honolulu?

Why is the magnetism of the earth of so much use to man?

CHAPTER III

PROPERTIES AND MAKE-UP OF MATTER

Forms of Matter. — The earth and the heavenly bodies are composed of a very great number of different substances. With some of these, such as iron, water, air, soil, plants, etc., we are all familiar. These, as well as all other substances, are called *matter*. In short, as scientists say, anything that occupies space — takes up room — is matter.

Matter is known to us in three forms: solids, liquids, and gases. All substances exist in one of these three forms. The forms of water are the most familiar illustrations of this truth: the most common form in which water is found is liquid; but as ice it is a solid, and as steam it is a gas. Metals such as iron, copper, tin, etc., may easily be changed by heat from a solid to a liquid form. Many metals found on the earth have been proved to exist as gases in the sun.

Properties of Matter. — Man is unable to comprehend how matter came into being, or how it can ever be utterly destroyed; but he does know many of the properties of matter.

Experiment 9. — Pull out the handle of a compression air-pump or bicycle pump. Close the exit valve or stop up the end of the bicycle pump. Now try to push in the handle. What keeps it from moving easily?

Try to shove an inverted drinking glass into a pail of water. (Figure 14.) Why does not the water fill the glass?

In the experiment with the air compressor we found that the space occupied by the air could be reduced only to a limited extent. Greater force might have compressed the air into smaller space, but no amount of force could reduce the air to a point where it did not occupy at least some space. When we pump up a bicycle tire, we see again that air demands room for itself. These examples illustrate the truth that all matter occupies room or space. This property of matter we call *extension.*

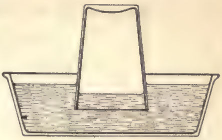


FIGURE 14

Experiment 10. — Place a coin on a smooth card extending slightly beyond the edge of a table. (Figure 15.) Suddenly snap the card horizontally. Does the coin move?

When the card was snapped from under the coin, the coin moved very slightly, if at all. The force of the finger was applied only to the card, and the card was so smooth that it did not convey any appreciable motion to the coin. If the coin had been glued to the card, both coin and card would have moved. This illustrates the truth that a body at rest does not begin to move unless some force acts upon it.

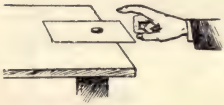


FIGURE 15

Experiment 11. — Revolve around the hand a small weight attached to a strong rubber band. Suddenly let go the band. Does the weight keep on moving in the circular path in which it was revolving?

When we let go the band, the weight started off in a straight line. (Figure 16.) It did not continue in a straight

line because a force called *gravity* pulled it down toward the earth. When a train is moving along a straight level track, we do not expect it to stop until the friction of the track or some other force stops it. A bullet fired from a gun will continue to move until it hits some unyielding object or is pulled to the earth by gravity. Thus we see that a moving body does not stop unless some force compels it to stop.

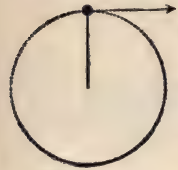


FIGURE 16

We may sum up these observations in the following words: A body at rest remains at rest unless acted upon by some force; a body in motion continues to move in a straight line at the same speed unless acted upon by an outside force. This property of matter is called *inertia*. Sir Isaac Newton first stated these facts, and so they are sometimes called *Newton's First Law*. We see this law frequently illustrated when standing passengers are jostled off their feet by the sudden starting or stopping of a car, or the swinging of the car around a sharp curve.

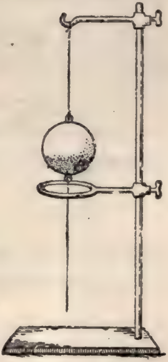


FIGURE 17

Experiment 12. — Suspend a heavy ball by a string not much too strong to hold it. (Place a pad beneath it to catch it if it drops.) Attach a similar string to the bottom of the ball. (Figure 17.) Attempt to lift the ball suddenly by the upper string. What happens? Suspend the ball again and lift it very gradually by the upper string. What happens? Now pull down suddenly on the lower string. What happens? Suspend the ball again and pull down gradually on the lower string. What happens?

When we tried suddenly to lift the suspended ball, the light string snapped because it could not withstand the sudden additional strain of overcoming the ball's inertia. When we exerted a very gradual pull on the upper string,

AIRPLANES

we overcame the inertia of the ball slowly and without sudden strain to the string.

When the lower string was suddenly pulled, it broke because the ball, through its inertia, withstood the sudden effort to change its position. But when the string attached to the bottom of the ball was pulled gradually, the upper string broke. In this case, the inertia of the ball was overcome without sudden strain to the lower string, and so this string had to withstand practically nothing but the pull of the hand. The upper string, on the other hand, had to

bear the double strain of the weight of the ball and the steady pull of the hand.

It is the inertia of the water which enables the small, rapidly revolving propeller to move the big ship. The resistance which the particles of air offer to being thrown suddenly into motion, their inertia, enables the propeller to pull the airplane along, and keeps the craft from falling to the ground as long as it is moving rapidly. It is owing

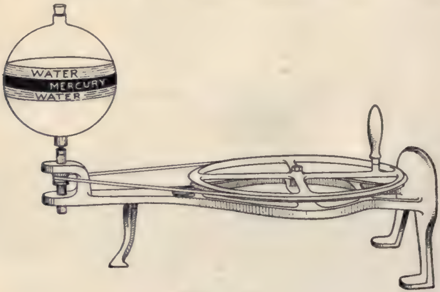


FIGURE 18

to inertia that the heavenly bodies keep on moving in space. Once in motion they must keep on forever unless some force stops them.

Experiment 13. — Place a glass globe partly filled with water and a small amount of mercury on a rotating apparatus. (Figure 18.) Rotate the globe rapidly. What do the water and mercury tend to do?

In Experiments 11 and 13 it was seen that revolving bodies tend to move away from the center around which they are revolving. This is a manifestation of inertia which is sometimes called *centrifugal force*. The weight

and the liquids tended to move away in a straight line, but they were kept from it by the band and by the globe. What happens when there is not sufficient restraining force is seen when the mud flies from the tires of a rapidly moving vehicle.

Newton many years ago discovered that all bodies of matter have an attraction for one another. What causes this no one knows, but the name given to this force of attraction is *gravitation*. Gravitation is always acting upon all bodies, and their conduct is constantly affected by it. It keeps the heavenly bodies from wandering away from one another, as the rubber band kept the weight from flying away from the hand.

Newton also discovered that the force of attraction between two bodies varies as the masses of the bodies; that is, the more matter two bodies contain, the more they attract each other. But this attraction becomes less as the distance between the bodies increases. The lessening of the force of gravitation on account of the increase of distance is proportional not to the distance but to the square of the distance. This means that if the distance between two bodies is doubled, the attraction between them is only one-fourth as great. Moved three times as far apart, the bodies have only one-ninth the attraction for each other; and so on.

When this attraction is considered in relation to the earth and bodies near its surface the term *gravity* is used. We are constantly measuring the pull of gravity and calling it *weight*. It is the force which causes us to lie down when we wish to sleep comfortably, and which makes all unsupported bodies fall to the earth.

If two forces act upon a body free to move, each will in-

fluence the direction of its motion, and it will go in the direction of neither force but in a direction between the two. If there are more than two forces, the path of the object acted upon will be the result of the action of all the forces. In the case of the weight and the rubber band we found that the moving weight when not held by the force of the band flew away from the hand. The rubber band continually pulled in toward the hand, while owing to inertia the weight tended to go off in a straight line. The result was that the weight neither went in toward the hand nor off in a straight line, but in a curved path.

THREE FORCES IN PLAY
See the accompanying diagram.

Planetary Movements. — We have seen that the sun is the great center around which the earth and the other members of the solar system revolve. The mass of the sun is so great that the attraction of gravitation between it and the planets holds these with their satellites in their paths and keeps them from flying off into space. In fact the laws of inertia and gravitation explain the entire mode of action of the heavenly bodies.

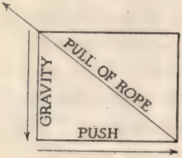


FIGURE 19

So thoroughly have mathematicians mastered these unvarying laws that they can tell just where in their orbits the earth or any of the planets will be at any future time, or were at any past time. The exact date of any eclipse in the future or in the past can be determined, and even the path of the moon's shadow across the earth. Disputed dates of events in ancient history which occurred during eclipses of the moon have been determined to the exact hour in this way.

One hundred years ago Uranus was thought to be the farthest planet in the solar system. But years of patient observation revealed the fact that its movement was not in exact accord with the schedule astronomers had mapped out for it. Two mathematicians, one in France and the other in England, working separately without each other's knowledge, concluded that this must be owing to the attraction of a more distant planet, as yet undiscovered. They calculated what must be the exact position of this planet. When on the night of September 23, 1846, a telescope was directed to this point, a half hour's search revealed the planet Neptune.

Composition of Matter. — It is the work of chemists to find out of what matter is composed. They tell us that all matter consists of minute particles, called *molecules*. These molecules are constantly moving about in the spaces that exist between them, hitting and bumping against one another.

The fact that minute invisible particles may be given off by a substance is readily shown by opening a bottle of ammonia or exposing a piece of musk in a room. Soon in every part of the room the presence of these substances may be recog-

nized by the odor. Yet nothing can in any possible way be seen to have been added to the air.

Experiment 14. — Dip a glass rod in strong hydrochloric acid and hold it a few inches above the open mouth of a bottle of strong ammonia water. Nothing can be seen to be emitted from either the rod or the bottle, but when they are brought near together a cloud of little white particles is formed. This must be due to the action of an invisible something which came from the ammonia upon an invisible something which came from the hydrochloric acid, resulting in the formation of something that is visible.

FIGURE 20

Molecules are too small to be seen by the most powerful microscope. There are millions of them in a particle of matter as big as the head of a pin. Some one has said that if a drop of water could be magnified to the size of the earth, the molecules would probably appear no larger than a baseball.

It has been found possible by chemical and electrical means to divide molecules into smaller particles called *atoms*, and very recently to find out something about the composition of the atoms themselves. For example, the smallest particle in which water can exist and still be water is a molecule. By means of an electric current these molecules can be broken up. But when we thus divide the molecules of water we no longer have water; we have two gases, hydrogen and oxygen.

Experiment 15. — (Teacher's Experiment). — Procure from the chemical laboratory an electrolysis apparatus or arrange an apparatus as shown in Figure 21. This consists of a glass dish partly filled with water to which a little sulphuric acid has been added. (The sulphuric acid is needed only to aid in carrying the electricity

between the platinum foils.) Two copper wires each having a small piece of platinum foil attached to one end are so arranged that the platinum foils extend up vertically in the water.

Fill two test tubes with the water in the dish and invert them over the platinum foils. To the ends of the copper wires attach a battery consisting of several dry cells. Bubbles of gas will begin to rise in the test tubes as soon as the battery is connected. One of the tubes will fill twice as fast as the other. When this tube is full quickly invert it and apply a lighted match to its mouth.

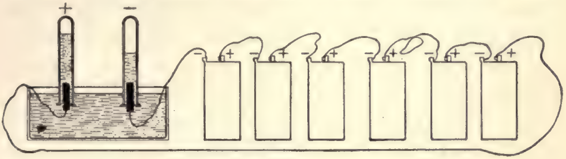


FIGURE 21

There will be a sharp explosion. This gas is *hydrogen*. Invert the other tube and insert a splinter with a glowing spark at its end. The spark will burst into flame. This gas is *oxygen*.

Chemists have learned that every molecule of water contains two particles of hydrogen and one particle of oxygen. These particles are called *atoms*. An atom of hydrogen is hydrogen; an atom of oxygen is oxygen — no other substance. For that reason, hydrogen and oxygen are known as simple substances and are called *elements*. But since the smallest particle of water — a molecule — is composed of hydrogen and oxygen, water is not a simple substance but a compound of two other substances. Chemists therefore call water a *compound*.

Every kind of matter known to man is classified as either an element or a compound. So far there have been discovered only about eighty elements — eighty substances that cannot be reduced to simpler substances. Among these are

iron, copper, tin, aluminum, lead, zinc, mercury, gold, silver, nickel. The gases hydrogen, oxygen, and nitrogen are also elements.

Most substances are compounds. The number of compounds as compared with the number of elements in nature may be illustrated in this rough way. There are only 26 letters in the English alphabet, but these may be combined in so many different ways that we have thousands of English words. Just so there are to our knowledge only about eighty different elements in the world. But these elements unite in so many different ways and in so many different proportions that we have innumerable compounds.

But the comparison of letters and words with elements and compounds must go no farther than to show how many more compounds there are than elements. The eye can pick out all the different letters that compose every word. But when the atoms of different kinds of elements combine into molecules, the resulting compound substance is so different from the elements composing it that there is no apparent relationship.

Water furnishes a good illustration. Oxygen is a gas that must be present wherever there is burning. Hydrogen burns very readily in the presence of oxygen. But water, every molecule of which is made up of atoms of these two gases and is the result of the burning of hydrogen in oxygen, is our main dependence for putting out fires.

Physical and Chemical Changes. **Experiment 16.** — Mix a little powdered sulphur with about half as much powdered iron or very fine iron filings. Examine the mixture with a magnifying glass. You can easily distinguish between the particles of iron and sulphur. Put the mixture into a test tube and heat it over a Bunsen burner. (Figure 22.) The mixture will glow and become a solid mass.

Break the test tube and examine the solid with a magnifying glass. Can you now distinguish the iron from the sulphur? The solid is a chemical compound called iron sulphide.

When water freezes it does not become a different substance; it is still water, but water in a solid state. When water is "boiled away" or evaporated by the heat of the sun, it is still water, but water in a gaseous state. When the iron used in Experiment 16 was pulverized it still remained iron. Such changes as these, which do not affect the nature of a substance, are called *physical changes*.

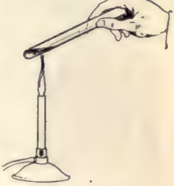


FIGURE 22

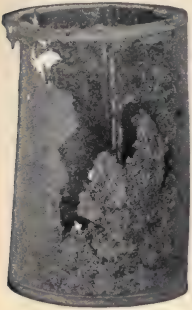
But when molecules break up into their atoms, or atoms unite to form molecules, a *chemical change* is said to occur. Such is the change that occurs when hydrogen and oxygen unite to form water; or when the electrical current breaks up the molecules of water into the two kinds of atoms composing them; or when sufficient heat is applied to an iron and sulphur mixture.

One of the most common examples of chemical change is the rusting of iron exposed to air. The atoms of oxygen in the air and in the water of the air combine with the iron to produce rust. A chemical change takes place and a compound of the two elements is formed which is entirely different in its nature from either.

A chemical compound such as iron rust, made up of oxygen and some other element, is called an *oxide*.

Mixtures must be carefully distinguished from *chemical compounds*. If we mix milk and water, neither the water nor the milk is really changed in nature as the result of putting them together in the same vessel. If we try to mix

oil and water their failure to combine into a third substance is even more noticeable. After a little while the water will be found at the bottom of the vessel and the oil, which is lighter, will float on top. A chemical compound is very different from such mixtures, as we learned in the case of water and of iron sulphide.



RUSTING OF IRON

Acids, Bases, and Salts. The most important chemical compounds for us to consider are *acids, bases,* and *salts.* Acids of various kinds exist in apples, grapes, rhubarb, buttermilk, vinegar, lemons, oranges, and other familiar substances.

A small amount of very dilute hydrochloric acid is formed in the stomach of man and of some other animals and helps in the process of digestion. Hydrochloric acid, sulphuric acid, and nitric acid are much used in the laboratories and in various industries.

Many acids are liquid; and dilute solutions (little acid in much water) of all common acids taste sour. Acids turn blue litmus paper to red. Litmus paper is paper which has been especially prepared by treating it with a vegetable substance called *litmus,* obtained from a low order of plants called *lichens.* Strong acids may cause great injury to cloth, paper, wood, or the flesh of animals.

It is important that we should become acquainted with another class of compounds called *bases* that are in some ways just the opposites of acids. Most bases are in the form of solids; and dilute solutions of almost all the bases

taste bitter. Litmus paper that has been turned red by acids will be changed back to blue by a base. Some of the most common bases of the household are ammonia water, baking soda, limewater, caustic potash (lye), and caustic soda. Certain strong bases are usually called *alkalies*. Caustic potash and caustic soda are two of the commonest and strongest alkalies.

Experiment 17. — Into a clean test tube containing pure water put a small piece of blue litmus paper. Pour into the test tube a little hydrochloric acid. What happens to the litmus paper? Now add a solution of caustic soda, drop by drop, until the litmus paper takes on a pale bluish red shade. Taste a drop of the solution in the test tube. The test tube will be found to contain water with common salt dissolved in it. By evaporating the water, crystals of salt may be obtained.

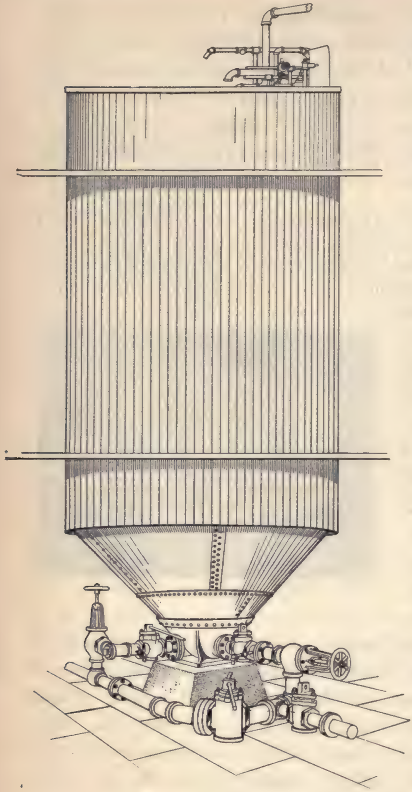
ROCK SALT

This process of combining an acid and a base in right proportions, by which a substance is produced that is neither an acid nor a base, is called *neutralization*. The result of such a chemical combination is water and a salt. There are many different kinds of salts; but the salt with which we are most familiar is sodium chloride, or common table salt, which resulted from the preceding experiment.

Strong acids and bases will corrode metals, discolor clothing, or even "eat" holes in it, and cause ugly flesh

wounds. But neutral substances will do none of these things.

A strong base like lye is just as dangerous to handle as a powerful acid. It is well to bear in mind then that bases and acids counteract or neutralize the destructive effects of each other. If lye is spilled on the hands or clothing, vinegar or lemon juice should immediately be applied to neutralize the base. If acid is spilled, ammonia water is the safest base to counteract it since it will do the least harm if too much is used.



Courtesy of The Procter and Gamble Company

KETTLE USED IN MANUFACTURE OF SOAP

This kettle is 16 feet in diameter, three stories high, and it holds about 375,000 pounds of soap.

Every housewife knows that am-

monia water may be used in a number of different ways to help remove grease from various kinds of fabrics, and that lye will act upon grease in such a way that water will dissolve it. Lye is therefore used for "cutting" the grease in drain pipes leading from sinks. But since lye and other strong bases which "cut" grease will also ruin most fabrics and will do harm to the skin, a milder cleansing agent must be found for laundry and personal use. Soap is one of those substances which chemists call *salts*, and is made by mixing or boiling fats with lye.

The neutralizing of acids by means of some mild base is a part of the daily experience of many people, even though they may not realize what the chemical action is. We put ammonia or damp baking soda on a bee-sting to neutralize the acid that the bee has injected into the flesh. Baking soda is used by housewives to sweeten sour milk. Frugal cooks sprinkle baking soda lightly over rhubarb, gooseberry, or cherry pie in order partly to neutralize the acids and thus to save sugar.

The farmer uses lime to "sweeten" a "sour" or acid soil. Physicians often prescribe limewater or a solution of baking soda to neutralize acidity (sourness) of the stomach. Fruit stains are caused by fruit acids. For that reason, the stains may usually be removed by soaking the linen in a weak solution of ammonia or borax.

The wonderful progress that man has made in the last century in manufacturing, transportation, agriculture, building, sanitation, and comfortable living conditions, has come out of his greatly increased scientific knowledge, and out of his increasing ability to control forms of energy which produce desired chemical and physical changes.

SUMMARY

Anything that occupies space is matter. Matter is known to us in three forms — solids, liquids, and gases. Matter has certain properties, such as extension, inertia, and gravitation. The laws of inertia and gravitation explain so perfectly the movements of the heavenly bodies that their courses may be accurately foretold.

All matter consists of particles called molecules, too small to be seen with the most powerful microscope. Molecules may be divided into smaller particles called atoms. If the molecules of a substance may be broken up into two or more kinds of atoms, the substance is called a compound; if not, it is called an element. There are about eighty elements known to scientists. All other substances are compounds.

When molecules of a substance gain atoms, lose atoms, or exchange atoms with molecules of other substances, a chemical change is said to occur. Any other kind of change in matter is a physical change. If when we combine two substances, the molecules remain unchanged, we have a mixture; if atoms of different kinds unite into molecules, we have a chemical compound.

Acids, bases, and salts are most important chemical compounds. Acids exist in many familiar substances. Many acids are liquid. Dilute solutions of common acids taste sour. Acids turn blue litmus paper red. Bases are in some ways just the opposite of acids. Most bases are solid and dilute solutions of them taste bitter. They turn red litmus paper blue.

Strong acids and bases are injurious to flesh or to common substances. The process of combining an acid and a base is called neutralization, and the result is water and a salt. A

salt has none of the caustic or corroding properties of bases and acids. Using some base to neutralize an acid is a common household experience. Strong bases like lye are used to "cut" grease from wood or metal. For milder cleansing purposes we use soap, which is neither an acid or a base, but a salt.

Questions

In what three forms does matter exist?

Name and illustrate three universal properties of matter.

What daily experiences of yours are explained by these three properties?

Why does a motorman slow up his car at a sharp curve?

What keeps the planets moving around the sun and in their orbits?

Of what do chemists regard all substances to be composed? Why?

What is the difference between a physical and a chemical change? Give an example of each.

In what respects do acids, bases, and salts differ from one another? Illustrate.

For what purpose have you ever used an acid, a base, or a salt?

CHAPTER IV

THE SUN'S GIFT OF HEAT

The sun is not only the ruler of the solar system in that it holds the planets in their orbits as they revolve about it; it also controls the activities upon the planets since it furnishes them with their heat and light. Without the heat of the sun the earth would be a cold, barren, lifeless, inert ball of matter and nothing more. The sun's gift of heat is all important.

Everybody has observed many of the effects of heat. It melts ice. It converts water into steam. It cooks food. Thus we see that heat has the ability to cause change. The capacity for causing change, for overcoming resistance, for doing work, is called *energy*. Heat is therefore a form of energy.

A body may have through its position or its composition the ability to do work without actually being at work. It is then said to have *potential energy*. The moment a body begins to do work, its energy is called *kinetic energy*. Either kind of energy may be transformed into the other.

A brick on a chimney top has potential energy owing to its position. If some force pushes it off, its potential energy is transformed into kinetic energy. When you wind a clock, the energy you expend is transmitted to the spring, and the spring is wound into such a position that it possesses potential energy. Thus your kinetic energy is stored up

in the spring as potential energy. Slowly the change of position of the spring transforms its potential energy back into kinetic energy.

When a gun is loaded with powder it has potential energy due to the composition of the powder. When the powder is exploded, the potential energy changes into kinetic energy which is imparted to the bullet. The smallest possible amount of nitroglycerine has potential energy on account of the arrangement of the atoms in its molecules. When that arrangement is disturbed, potential energy becomes kinetic and an explosion results.

Courtesy of Illinois Central Railroad

A PILE DRIVER IN ACTION

The weight or "ram" is lifted to the top of the machine, where it has great potential energy. As it falls, it changes its potential energy into kinetic energy and drives the pile.

The sun throughout its existence has been sending vast quantities of energy to the earth. This energy has been mostly in the forms of heat and light.

The ability of the earth to support plant or animal life or to furnish man the power necessary to carry on his industries is due to the energy furnished by the sun. Plants cannot grow without the energy furnished by the sunlight, and animals could not live were it not for the energy furnished them by the plants.

We often think that there are many different sources of energy such as waterpower, wood, coal, oil, and others; but when these are traced back, their energy is found to have come from one source, the sun. The water which the sun has evaporated and carried by cloud and shower to the mountain lake is stored there and has potential energy. It is ready to run down the valleys changing its potential energy into kinetic and doing work. Without the heat of the sun there would be no life upon the earth, no flowing streams, no changing winds, none of the restless energy which makes the world as we know it.

For untold ages plants utilized the sun's energy and stored it up. It was preserved in the remains of plants in the form of coal. This coal is now being burned to furnish power to carry on man's industries. Thus nature has run a savings bank. The sun's kinetic energy was transformed and stored for ages in the earth's vaults as potential energy, and now issues from the burning coal as kinetic energy to do our bidding.

The motion of the falling brick was a manifestation of energy due to gravitation. The explosion of the gunpowder was due to chemical energy. The ordinary street car runs by virtue of electrical energy. Thus we see that there are other *forms of energy* besides heat and light. But one form of energy may be readily changed into another form, as when the steam engine transforms the energy in coal into

mechanical energy, or when this mechanical energy is changed by the dynamo into electrical energy. (Figure 23.)

If you have ever bored a hole in hard wood, you have noticed how hot the point of the drill becomes. A portion of the energy you expended went to displace the particles of wood, and a portion of your energy was transformed by friction into heat. The portion of your energy which was transformed into heat is usually referred to as lost energy, because it did not help to accomplish the work you set out

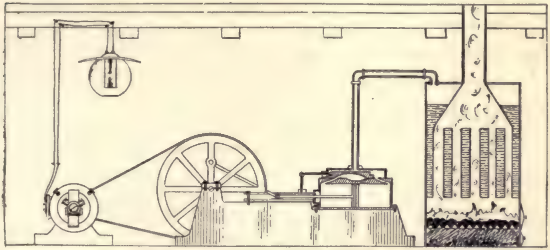


FIGURE 23. — TRANSFORMATION OF ENERGY

to do. Whenever man undertakes to change one form of energy into another, there is always this "loss of energy."

In a factory, for example, a great deal of the heat from the burning fuel goes up the chimney and is also lost in other ways. Even that part of the heat which is transformed into mechanical energy cannot all be utilized. Much of it is transformed back into heat by the friction of the moving parts of the machinery.

In reality, however, no energy is ever lost or destroyed. It may be lost in the sense that it does not serve man's immediate purpose, but it has not gone out of existence. The same thing may be said of energy that was said of

matter. Man can neither create it nor destroy it. He may only transform it. This great truth has been determined by a vast amount of most careful investigation, and is called the *law of conservation of energy.*

Some Effects of Heat. — The following experiments illustrate a common effect of heat.

Heat. — Experiment 18. — Fit a glass flask with a one-hole rubber stopper through which passes a glass tube about 20 cm. long. Place this on a ringstand so that the end of the tube extends down into a bottle nearly filled with water. (Figure 24.) Gently heat the flask. The air expands and bubbles rise in the water. When the flask cools, the air contracts and water rises in the tube.

FIGURE 24

Experiment 19. — Fill the flask used in the last experiment with colored water. See that the end of the glass tube passing through the rubber stopper is just even with the bottom of the stopper. Smear the lower part of the stopper with vaseline and insert it in the flask, being careful that the flask and a few centimeters of the tube are filled with the colored water and that there are no air bubbles in the flask. Mark, by slipping over a rubber band, the end of the water column in the tube. (Figure 25.) Heat the flask. The water expands.

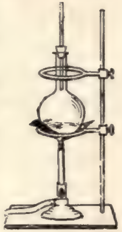


FIGURE 25

Experiment 20. — Pass the ball of a ball-and-ring apparatus through the ring. (Figure 26.) Notice how closely it fits. Heat the ball in a Bunsen flame for several minutes. See if the ball will now go through the ring. Explain why it does not.

FIGURE 26

We saw in these experiments that heat caused the gas, the liquid, and the solid to expand. Cooling had the reverse

effect. On every hand expansion and contraction due to changes in temperature must be taken into account. The ends of steam pipes are allowed to be free and are never attached firmly. The ends of the spans of long iron bridges are placed on rollers. In places where there are considerable ranges of temperature concrete sidewalks are cut into squares instead of being laid as continuous solid surfaces. When iron tires are fitted to wagon wheels they are first heated and then placed on the wheels and allowed to cool. Telephone wires are tighter in winter than in summer. For this reason they are not stretched taut when put up.

FIGURE 27

Experiment 21. — Heat a metal compound bar. It bends over on one side. The more the bar is heated the more it bends. (Figure 27.) The two metals do not expand at the same rate.

Various solids and liquids expand and contract at different rates. Platinum expands and contracts at almost the same rate as glass. When platinum and glass are fused together they expand and contract almost as one substance. For this reason, in the manufacture of incandescent lamps, platinum is the only substance that can be used to pass through glass to carry the electrical current to the filament within. Other metals contract either more rapidly than the glass and thus let air into the bulb, or more slowly and thus break the glass. One reason why mercury is used in thermometers is that it changes rapidly in volume with changes in temperature.

Different parts of the same substance will expand at different rates according to the amount of heat applied. When experienced housewives wash glasses in hot water, they do not dip them slowly; they plunge them in quickly

so as to allow them to expand at the same rate throughout and thus to prevent their breaking. This explains why it is unwise to pour boiling water slowly into a cold glass, or cold water slowly into a hot glass.

The experiment with the ball-and-ring apparatus easily makes clear the meaning of the terms *mass, volume, density,* and *weight,* which we shall have occasion to use from time to time. After the iron ball was heated, it contained no more iron than before it was heated. The amount of matter in it, its *mass,* remained the same. But under heat the iron expanded and occupied more space; that is, its *volume* was greater. Heat increased the volume, but not the mass, of each of the substances we experimented upon.

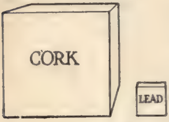


FIGURE 28. — EQUAL MASSES OF CORK AND LEAD

We all know that some substances are heavier than others. A cubic inch of lead, for example, is heavier than a cubic inch of cork. We say that the lead has greater *density* than the cork; that is, a piece of lead has more matter in it than a piece of cork of the same volume. (Figure 28.)

Weight is simply the measure of attraction between the earth and the body weighed. The greater the amount of matter, the greater is the attraction between it and the earth; that is, the greater its weight. Weight, however, must not be confused with density. The farther away a substance is from the center of the earth, the less it weighs. (Page 47.) A cubic inch of lead would weigh appreciably less at the top of a high mountain than at the level of the sea. But the density of the lead would not be affected by its distance from the earth's center.

When the iron ball was heated, its volume was increased,

its density was decreased, but its mass remained the same. Since the mass remained the same as before heating, and its distance from the earth's center was unchanged, it weighed the same as before.

When heat was first studied it was thought to be an invisible fluid without weight which worked itself into bodies and caused them to expand in the same way that water affects a sponge or a piece of wood. This fluid was supposed to be driven out by pounding or rubbing. Even the primitive savages knew that fire could be obtained by rubbing two dry sticks together.

About the close of the eighteenth century an American, Count Rumford, who was boring some cannon for the Bavarian government, showed that the amount of heat developed seemed to be entirely dependent upon the amount of grinding or mechanical energy expended. The old theory of a fluid prevailed, however, until about the middle of the nineteenth century, when a great English experimenter by the name of Joule showed conclusively that the amount of heat developed was due entirely to the amount of energy which apparently disappeared into the heated body.

We learned in Chapter III that all matter consists of constantly moving particles, or molecules, with spaces between them. When a substance is heated the molecules move more rapidly and strike each other harder. This drives the molecules farther apart and causes the substance to expand. Heat is a form of energy which manifests itself in the motion of these molecules of matter. If a condition could be reached where there was no molecular motion, there would be no heat.

If we apply sufficient heat to ice, the molecules hit against one another so rapidly and so hard that the ice loses its defi-

nite shape and melts down into water. If now we apply sufficient heat to the water, the motion of the molecules becomes so violent that they fly off from one another in steam. But while this effect of heat in changing ice to water and water to steam is familiar to us all, it is not so generally known that the application of sufficient heat will change other substances from a solid to a liquid and from a liquid to a gaseous state.

Iron, for instance, may be solid as we ordinarily see it, or liquid as it comes from the blast furnace, or gas as it exists in the indescribably hot atmosphere of the sun. When heat is withdrawn, the processes are reversed, from gas to liquid and then to solid.

Some substances, such as camphor, pass from a solid state directly to a gaseous state. Even ice may do this under certain conditions. Housewives in cold climates know, for example, that clothes on the line will "freeze dry" in zero weather.

Substances usually expand as they change from the solid state to the liquid state, and contract when the process is reversed. Ice is a notable exception to this general rule, since when water freezes its volume increases. If it were not for this, ice would not float. Certain metals such as cast iron also have the property of expanding at the moment of solidifying. Type metal is a mixture of metals that possesses this property. It is poured into the molds in a molten condition. When it solidifies it expands and forces itself into every available crevice, thus taking on the sharp outlines that type must have.

Substances always increase in volume as they change from a liquid to a gaseous state. Engineers roughly estimate, for example, that a cubic inch of water makes a cubic foot of steam.

Courtesy of American Steel Foundries

MOLTEN STEEL FLOWING FROM A BLAST FURNACE

The liquid steel is here conducted by a duplex spout into two 20-ton ladles, ready for casting in the molds.

Production of Heat. — Heat may be produced in several different ways, but the most common way is by burning. Our houses are usually heated by burning wood or coal. If we wish the fire in the stove to burn more brightly we open the draft; if more slowly, we close it. Apparently

the supply of air has much to do with the fierceness of the fire.

Experiment 22. — Wind a short piece of wire around a small piece of candle and after lighting the candle lower it into a wide-mouthed bottle. Insert a stopper into the mouth of the bottle. The candle will begin to smoke and will soon go out.

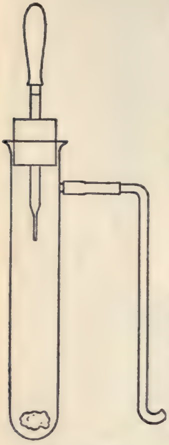


Figure 29

From the foregoing experiment it appears that a supply of air is necessary for the burning of the candle. Experience shows that this is true in all the forms of combustion familiar to us.

Experiment 23. — (Teacher's Experiment.) — Obtain four bottles of oxygen from the chemical laboratory. If not obtainable, place a piece of sodium peroxide (oxone) about as large as the end of a finger in a side-necked test tube provided with a medicine dropper filled with water, as shown in Figure 29. Put the end of the delivery tube under the mouth of an inverted bottle filled with water arranged on the shelf of a pneumatic trough. Drop water slowly on to the sodium peroxide and collect the gas generated. Fill several bottles. Oxygen can also be prepared by heating a mixture of about one part manganese dioxide and two parts potassium chlorate in a test tube and collecting the gas over water. (Figure 30.) Does the appearance of this gas differ in any way from air? Smell of it. Has it any odor? Into one of the bottles of oxygen insert a splinter of wood having a spark at the end. It bursts

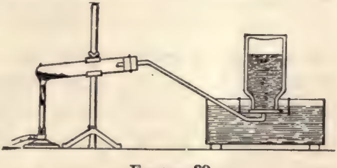


Figure 30

into flame. Does the same thing take place when the stick with the spark upon it is held in a bottle of air?

Hold a lighted match at the mouth of another of the bottles containing oxygen. Does the gas itself burn as illuminating gas does when a match is applied to it? If the oxygen in the air were increased or decreased, it would have a great effect upon combustion. Attach a piece of sulphur to a short piece of picture wire. Ignite it and place the wire in a bottle of oxygen. (Figure 31.) Does the sulphur burn strongly? How about the wire? Does it burn too?

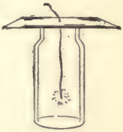


FIGURE 31

In the experiment just performed, we found that substances burn in oxygen much more fiercely than in air, and that substances which do not burn in air readily burn in oxygen. Experiments have shown that oxygen, a gas which is in the air about us, must be present where burning occurs. In fact burning is the result of the chemical union of atoms of oxygen with atoms of other substances.

The paraffin in the candle is a compound that contains both hydrogen and carbon. These two elements are found in all common fuels and are sometimes called *fuel elements*. Both of them readily unite under proper conditions with oxygen, and the chemical action produces heat. When wood or coal burns, the atoms of the fuel elements in these substances unite with atoms of oxygen.

Experiment 24. — (Teacher's Experiment.) — Put a few zinc scraps in a test tube and pour a little hydrochloric acid upon them. Feel the test tube near the zinc.

Put half an inch of water into another test tube and carefully pour a little strong sulphuric acid down the sides of the tube into the water. Feel the tube.

Burning is not the only way in which chemical action produces heat. In the preceding experiments, both test

tubes were found to have been heated by the chemical action which took place, but no combustion occurred.

But chemical action is only one of the sources of heat. Every Boy Scout is taught to make a fire by rubbing two pieces of dry wood together. (Figure 32.) He knows that friction is a method of producing heat; or to state it another way, the mechanical energy of rubbing is transformed into heat energy. We shall find in Experiment 157 that electrical energy can be changed into heat energy. The change of chemical, mechanical, and electrical energy into heat energy are the three ways in which we produce heat.

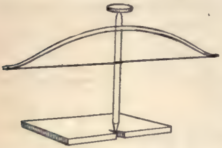


FIGURE 32. — BOY SCOUT OUTFIT FOR MAKING FIRE

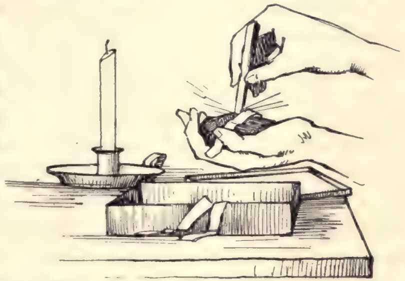
Kindling Temperature. — We have found by experience that a certain amount of heat is necessary to get things to burn. Two sticks have to be rubbed until they are very hot before they take fire. We use kindling to get large pieces of wood and coal hot enough to burn. Everything has to be brought to a certain temperature before it will take fire. This temperature is called the *kindling temperature.*

The kindling temperatures of different substances vary greatly. The kindling temperature of phosphorus is a little below the temperature of the human body, and phosphorus is therefore a dangerous thing to handle. The kindling temperature of iron is many hundreds of degrees.

Certain substances very readily unite with the oxygen of the air at ordinary temperatures and, by so doing, of course produce heat. If the heat thus produced does not escape,

the substances will in time be raised to their kindling temperature and will take fire. This is called *spontaneous combustion.*

Linseed oil used by painters is a substance which readily oxidizes. Accumulations of rags saturated with such oil will gather heat of oxidation (if in a place where there is no great movement of air) until the kindling temperature is reached, and a fire is started. Sometimes the dust in the center of a great pile of coal produces heat enough by its oxidation to start a fire in the coal. Sometimes the heat produced by the "souring" of hay is sufficient to set the hay on fire.



Tinder Box and Flint and Steel

A means by which substances can be readily brought to their kindling temperature is very essential if fires are to be easily built. Our forefathers used to strike a flint and steel together so as to make a spark fall upon some fine, dry material (tinder). With this they patiently started the larger fires they needed.

In frontier days, smoldering tinder was kept in a "tinder box," and this served the pioneers instead of matches. Until less than a hundred years ago the use of flint and steel was the prevailing method of obtaining fire.

This method of starting fire was difficult and uncertain. The invention of the friction match has changed all this and

made the production of fire easy and certain. It has been one of the great factors in making life comfortable. The earlier matches consisted of a splinter of wood tipped with a mixture of sulphur, yellow phosphorus, potassium chlorate or red lead, held together by glue. When struck on a rough surface the heat of friction was sufficient to ignite the phosphorus, thus causing the other materials to burn and the splinter of wood to catch fire.

It was soon found that the use of ordinary phosphorus was very dangerous to the matchmakers, causing a dreadful bone disease. For that reason, the use of ordinary phosphorus in the making of matches has now been practically abolished, and a harmless compound containing phosphorus is usually substituted in its place. But since friction against any rough surface will ignite the ordinary match, nibbling mice and busy-fingered children have often started disastrous fires with them. Because of that the safety match was invented, which will not ignite by friction on any ordinary rough surface.

On the tip of the safety match there is no phosphorus nor phosphorus compound, but only substances that burn readily and contain a great deal of oxygen. The side of the match box is used for a striking surface. It is coated with several substances, among which is red phosphorus. The only way red phosphorus can easily be ignited by friction is to rub it with some substance that is rich in oxygen. The oxygen-bearing materials on the tip of the safety match strike a spark out of the red phosphorus, which in turn ignites the match head.

Saving Fuel. — **Experiment 25.** — (*a*) After closing the holes at the bottom of a Bunsen burner, turn on the gas and light it. The flame is smoky. Heat a piece of wire in it. It heats slowly.

Open the holes. The flame ceases to smoke. Place a wire in it. It heats quickly. Regulate the sizes of the openings until the greatest possible heat is obtained.

(*b*) By means of a ringstand hold a wire gauze two or three inches above a Bunsen burner. Turn on the gas and apply a lighted match above the gauze. The gas above the gauze will take fire, but that below will not. (Figure 33.) Turn off the gas and then turn it on again. Now light the gas below the gauze. The gas above the gauze does not ignite. The gauze conducted the heat off so rapidly into the surrounding air that the gas on the side of the gauze away from the flame was not raised to its kindling temperature and so did not burn.

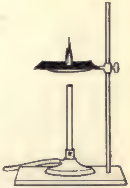


FIGURE 33

In Experiment 25 it was found that if the holes at the bottom of a Bunsen burner are closed so that an abundant supply of air (that is, of oxygen in the air) is not mixed with the gas, the burner smokes. When these holes are regulated so that the right amount of air is supplied, there is a hot flame and no smoke. It was found in the second part of the experiment that gas would not burn unless it was raised to its kindling temperature. This illustrates what happens, to a greater or less extent, in all stoves and furnaces — especially where soft coal is burned.

Every one knows that when a fresh supply of soft coal is thrown upon a fire, it smokes. This is because the fresh coal acts as a blanket. It decreases the supply of fresh air from below, and lowers the temperature in the upper part of the stove or furnace. Not all the gases from the coal that are driven off by the heat below are burned where they are formed, because the blanket of coal has cut down the draft and thus lowered the supply of oxygen.

These light gases rise, therefore, into the upper part of

the stove or furnace, where the supply of oxygen is even more scant and the temperature is below the kindling point of the gases. The result of this incomplete combustion is that part of the carbon in the gases is set free and floats away in the form of smoke.

This not only results in the formation of the smoke nuisance in cities but also in a great loss of available heat. It is estimated that in Pittsburgh alone the loss of heat due to

Courtesy of Underfeed Stoker Company of America

BEFORE INSTALLING AN UNDERFEED FURNACE

When a blanket of fresh fuel is thrown on the glowing coals, great quantities of carbon and fuel gases escape as smoke. This may be likened to burning a candle upside down.

non-combustion of smoke has been fully $10,000,000 in a single year. This is aside from the tremendous total damage to clothing, house furnishings, and stocks of merchandise, and from its menace to health.

In order to burn the gases that rise to the upper part of the stove or furnace, there must be a supply of fresh air above the burning coal. When a furnace has too heavy a draft from below, and no supply of fresh air through the feed door, unburned fuel gases are driven up the chimney.

With proper arrangements for putting the coal upon the fire in small quantities so as not to cut off the draft suddenly or lower the temperature of the upper part of the stove too greatly, a great saving of heat can be realized and one of the worst nuisances of a modern city largely avoided.

Many cities require the use of smoke-consuming furnaces in all large buildings. Most of these are so arranged that the gases formed where the fresh supply of coal meets the

Courtesy of Stoker Underfeed Company of America

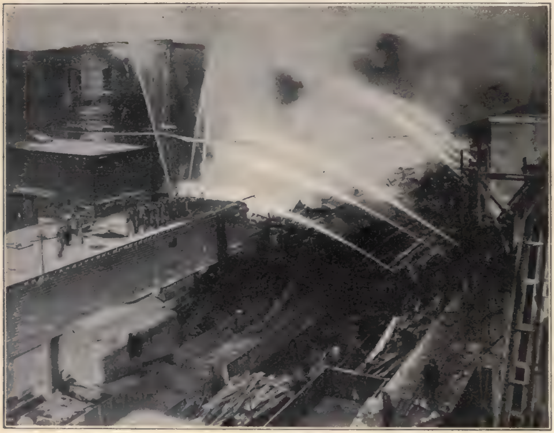
After Installing an Underfeed Furnace

In this furnace the fire is constantly above the fresh fuel, and the volatile gases and carbon are consumed as they pass up through the fire. This acts like a burning candle right side up.

glowing coals are conducted through the fire and largely consumed. Contrivances known as smoke consumers are sometimes attached to small furnaces. Abating the smoke nuisance is a problem that deserves the most careful consideration by the authorities of all cities. It involves the conservation of both health and wealth.

Control of Fire. — Fire under control is man's best friend. Fire makes our homes comfortable in winter, cooks our food, lights many of our houses, is used somewhere in the

manufacturing of practically everything we use, furnishes power for most of our transportation, and in fact makes life livable. But when fire gets out of control it ruthlessly destroys almost everything it can touch. The control of fire is, therefore, exceedingly important. We have seen (page 70) that fire cannot exist unless oxygen is



FIRE OUT OF CONTROL

Fighting the great conflagration at the Chicago stockyards in 1910.

present. Therefore to control fire it is only necessary to shut off the oxygen. Closing the draft of a stove cuts down the supply of oxygen.

When water is put on a fire it not only shuts off the supply of oxygen but it also cools the burning material below its kindling temperature. Water, however, is not serviceable for extinguishing such substances as burning oils, since the

burning oil floats on the water and the expansion of any generated steam throws the flaming oil about and thus spreads the fire. In a case of this kind, sand or a woolen blanket serves the purpose better.

Wool does not readily burn, and when the blanket is thrown over the burning oil, the air is shut off and the fire put out. If one's clothing takes fire by accident, one should never run. A rug or a blanket rolled about the body is the most effective means of putting out the fire. If one is outdoors, rolling in the dust, or heaping dust on the flames, will cut off the oxygen supply. The chief thing to remember is to cut off the air supply immediately.

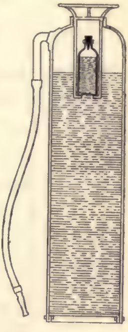


FIGURE 34. — DIAGRAM OF A FIRE EXTINGUISHER

Experiment 26. — (Teacher's Experiment.) — Get two or three bottles of carbon dioxide from the chemical laboratory, or prepare it by pouring dilute hydrochloric acid upon pieces of limestone in a bottle and collecting the gas over water. Does the appearance of this gas differ in any way from that of air? Smell of one of the bottles that has stood over water for some time. The gas has no odor. Plunge a lighted match into one of the bottles containing the carbon dioxide. What happens? Does the gas burn or support combustion? Slowly overturn a bottle of the gas above a lighted candle. The candle is extinguished. The gas falls out when the bottle is overturned, thus showing that it is heavier than air. If the amount of carbon dioxide in the air were largely increased, what effect would it have upon combustion?

The ordinary chemical fire extinguisher (Figure 34) consists of a strong metal cylinder nearly filled with a solution of baking soda. Held firmly in the top of the cylinder is a

bottle of sulphuric acid. There is an opening in the top of the cylinder which is connected with the nozzle by means of a short strong rubber tube. When the extinguisher is to be operated, it must first be inverted. The acid falls out of the bottle, and mingling with the solution of baking soda rapidly generates carbon dioxide. The pressure of this generating gas forces the solution mixed with the gas out of the nozzle. Since carbon dioxide will not burn and is considerably heavier than air, it helps the water to smother the fire. Chemical fire-engines make use of this same gas.

Measurement of Temperature. — It has been seen (pages 64 and 65) that gases, liquids, and solids expand when heated and contract when cooled. It has been found that most substances expand uniformly through ordinary ranges of temperature, so that if this expansion or contraction is measured, we are able to determine the change of temperature.

FIGURE 35

Experiment 27. — Slightly warm the bulb of an air thermometer tube and place the open end in a beaker half filled with inky water. (Figure 35.) Allow the bulb to cool. The tube will become partly filled with the water. When the bulb has become cooled to the temperature of its surroundings, mark the end of the water column with a rubber band. Grasp the bulb with the hand, thus warming the air in it. The water column will run partially out of the tube back into the beaker. Cool the bulb with a piece of ice or a damp cloth. The water will come farther up in the tube than it did when simply exposed to the air. We have here an apparatus for telling the relative temperatures of bodies.

Instruments arranged to show changes in temperature by the amount of the expansion or contraction of certain materials, are called *thermometers*. These may be gas,

liquid, or metal thermometers. There must be some uniform temperatures between which the expansion shall be measured if we are to have a basis of comparison. These definite points have been taken as the freezing and boiling points of water at sea level.

Experiment 28. — (Teacher's Experiment.) — Fill a four-inch ignition tube with mercury and insert a one-hole rubber stopper having a straight glass tube extending through it and about 20 cm. above it. (Figure 36.) It may be necessary to cover the stopper with vaseline to keep out air bubbles. When the stopper was inserted the mercury should have risen a few centimeters in the tube. Mark with a rubber band the end of the mercury column. Gently warm the ignition tube. The mercury column rises. Cool the tube and the column falls. We have here a crude thermometer.

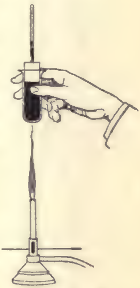


FIGURE 36

The substance whose expansion is most commonly used to measure the degree of temperature is mercury. This expands noticeably for an increase in temperature and the amount of its expansion can be very readily determined. The ordinary thermometer consists of a glass tube of uniform bore which has a bulb at one end. The bulb and part of the tube are filled with mercury. The remaining part of the tube is empty, so that the mercury can freely rise or fall. When the temperature rises, the mercury expands and rises, when the temperature falls, the mercury contracts and sinks.

There are two kinds of thermometer scales commonly used. The one which is used almost exclusively in scientific work and in those countries where the metric system of weights and measures has been adopted, is called the *Cen-*

tigrade. In this scale the point to which the mercury column sinks when submerged in melting ice is marked 0°, and the point to which it rises at sea level when immersed in unconfined steam (the boiling point of water) is 100°. A degree Centigrade, then, is $\frac{1}{100}$ the distance the column expands when heated from freezing to boiling.

FIGURE 37. — CENTIGRADE AND FAHRENHEIT SCALES COMPARED

The common household thermometer of this country and England is the *Fahrenheit* thermometer. It is named after its inventor, who about two hundred years ago began the making of thermometers. He found that by mixing ice and water and salt he obtained a temperature much lower than that of freezing water. This temperature he took as his zero point. In this scale the point at which ice and snow melt is marked 32°, and the point at which water boils at sea level is marked 212°. The distance between the boiling point and freezing points is divided into 180 equal parts, or degrees. A degree Fahrenheit, then, is $\frac{1}{180}$ the distance the column expands when heated from freezing to boiling, instead of $\frac{1}{100}$ as in the Centigrade scale. (Figure 37.)

There are a number of different designs of thermometers. Some are for measuring very high, others for measuring very low, temperatures. Thermometers are also constructed so as to be self-recording. (Figure 38.)

The Measurement of Heat. — **Experiment 29.** — In each of two beakers or tin cups weigh out 100 g. of water. Carefully heat

one of the beakers until the water when thoroughly stirred shows a temperature of 90° C. Cool the other beaker till the temperature of the water is 10° C. Pour the water from one beaker into the other, and after thoroughly stirring note the resulting temperature. Use a chemical thermometer to determine the temperatures.

Weigh out 100 g. of fine No. 10 shot in a tin cup and 100 g. of water in another. Place the cup containing the shot in boiling water and allow it to remain, stirring the shot occasionally, until its temperature is 90° C. Cool the water in the other beaker until its temperature is 10° C. Determine the temperatures exactly and then pour the shot into the water. After thoroughly stirring determine the temperature of the mixture. Which has the highest temperature, the mixture of water and water or the mixture of shot and water?

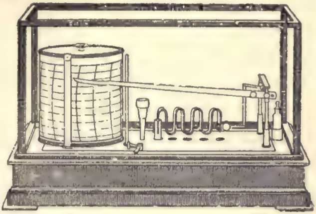


FIGURE 38. — A SELF-RECORDING THERMOMETER

Since heat plays such an important part in the activities of the earth, we need to know how to measure it. There is a great difference between temperature and the amount of heat. The amount of heat in a spoonful of water at 100° would be very much less than in a pailful of water at 10°. It would require more heat to raise a pond of water a small part of a degree than to raise a kettleful many degrees. That is why large bodies of water, although their temperatures never greatly change, are able to absorb and to give out great amounts of heat.

Not only does the amount of heat necessary to raise the temperature of different quantities of the same substance vary, but the amount of heat necessary to raise the tem-

perature of equal quantities of different substances also varies. If a pound of water and a pound of olive oil are placed side by side in similar dishes on a stove, it will be found that the olive oil increases in temperature about twice as fast as the water, *i.e.* it takes about twice as much heat to raise water as it does to raise the same weight of olive oil one degree. In fact, it takes more heat to raise a given weight of water one degree than it does to raise the same weight of almost any other known substance.

In Experiment 29, the resulting temperature from the water mixture was much higher than from the water and shot mixture. The shot has much less capacity for heat. The quantity of heat required to raise the temperature of a certain mass of a substance one degree compared to the quantity of heat required to raise the same mass of water one degree is called the *specific heat* of that substance. The specific heat of olive oil is .47, of shot .03. That is, it takes .47 as much heat to raise a given mass of olive oil and .03 as much heat to raise a given mass of shot one degree as it does to raise a corresponding mass of water one degree. In order to compare different quantities of heat, physicists have taken as the unit of measure the quantity of heat required to raise the temperature of one gram of water through one degree C. This unit is called a *calorie*.

The Effect of Heat upon the Condition of a Substance. — **Experiment 30.** — Having filled two tin cups or beakers of the same size to an equal height, one with water and the other with a mixture of water and ice, place them side by side on a stove or over Bunsen burners so adjusted as to give approximately the same amount of heat. (Figure 39.) Stir each with a chemical thermometer, and make a note of its temperature.

After heating a few minutes, stir again and note the temperature. Have there been like changes in the temperatures of the

two cups? Continue to stir and note the changes until the ice is melted. Do your notes show that like amounts of heat have produced like changes of temperature in the two cups? Continue to heat, stirring and noting the temperatures occasionally. Is there now an approximately equal rise of the temperatures of the water in the cups?

When the water in one cup begins to boil, does its temperature continue to rise as fast as that of the water in the other cup? What apparently became of the heat delivered to the ice-water before the ice melted? What apparently became of the heat delivered to the water while it is boiling?

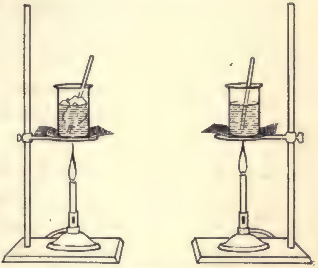


FIGURE 39

The preceding experiment shows that heat is absorbed in melting ice, and that the heat so absorbed does not raise the temperature of the ice. It also shows that heat changes water into steam, and that although very much heat was applied none of it was used in raising the temperature of the boiling water but all of it in changing the condition of the water.

Carefully performed experiments show that it takes 80 times as much heat to change a gram of ice at 0° C. into water at 0° C.; and about 536 times as much to change a gram of water at 100° C. into steam at 100° C. as it does to raise the temperature of the same mass of water one degree C. The heat absorbed in changes of this kind is called *latent heat*. It is all given out again when the water freezes or the steam condenses.

This explains why ice melting in a refrigerator takes so

much heat from the air and food about it and keeps them cool. It also explains why so much heat is given out when the steam in a steam radiator condenses into water, and why steam heating is the most effective way of heating houses in cold climates.

Many of us have noticed that when we have a *quiet* snowfall the temperature usually rises. This is because the heat given out by the changing of the vapor in the air into snow is not carried by the air currents to another region but warms the local atmosphere. Many similar phenomena are explained by this experiment.

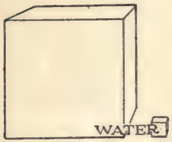


FIGURE 40. — COMPARATIVE EFFECTS OF HEAT

The amount of heat required to change the smaller mass of water into steam without altering its temperature would raise the temperature of the larger volume one degree.

The Transference of Heat. — Some one has stated a truth playfully in saying that "no substance is ever selfish with the heat it possesses." Any hot object left for a long enough time in cooler surroundings will yield up its heat until it is of the same temperature as its surroundings. Any cold object placed in warm surroundings will receive heat until it is eventually of the same temperature as its surroundings.

If water is placed on a hot stove it will absorb heat until it passes away in steam. If hot water is allowed to stand in a room, it will give off its heat until its temperature falls to that of the room. When ice is placed in a refrigerator the heat of the contents of the refrigerator is yielded up to the ice and melts it. If a refrigerator could be so constructed that no warmth could reach its interior, the contents would eventually become as cold as the ice.

Experiment 31. — Cut off 15 cm. of No. 10 copper and No. 10 iron wire and the same length of glass rod of about the same diameter. Holding each of these by one end place the opposite end in the flame of a Bunsen burner. Which of the three conducts the heat to the hand first?

Experiment 32. — Fill a test tube about $\frac{3}{4}$ full of cold water. Holding the tube by the bottom carefully heat the top part of the water until it boils. Be sure that the flame does not strike the tube above the water, else the tube will break. (Figure 41.) A little piece of ice in the bottom of the test tube makes the action more apparent. A bit of wire gauze or a wire stuffed into the test tube will prevent the ice from coming to the surface. Water conducts heat poorly. The hot water does not sink. Do you conclude that the warm water is heavier or lighter than the colder water?

FIGURE 41

Through solid substances, such as metals, heat travels quite readily; through others, such as glass, less rapidly. In Experiment 31, we found that heat traveled along some rods faster than it did along others. In no case, however, was there any indication that there was a transference of the particles composing the rods. In the boiling of the water at the top of the test tube, there was no indication that the water particles moved to the bottom of the tube. In these cases, the heat is simply transferred from molecule to molecule.

This kind of heat transference is called *conduction*. In transference by conduction each molecule acts as a messenger, passing the heat energy on to another that it *touches*. If two different substances touch each other, the molecules of one substance may conduct heat to the molecules of the other; but the two substances must be touching each other or the method of transference cannot be called conduction.

Conductors may be good or bad, as was shown by the

different materials used in the experiments. One of the reasons why we use iron for our radiators is that the heat of the steam may readily pass from the inside to the outside of the radiator. We cover our steam pipes with asbestos when we wish to retain the heat, because asbestos is a poor conductor and will keep the heat in the pipes.

On a cold day good conductors of heat feel colder than other objects because they quickly conduct the heat away from the hand. For that reason, a metal door knob seems much colder than the door in winter. On a very warm day good conductors feel hotter than other objects because they conduct their heat to the hand rapidly. The metal knob, therefore, seems much warmer than the door when the bright sun is shining on them both in summer.

This explains why tile and concrete floors feel cold, and why we cover them with rugs, which are poor conductors of heat. A woolen blanket feels warm, and a cotton sheet cold, for the same reason. There is really no difference between the warmth of these objects if they are in surroundings of the same temperature.

FIGURE 42

Experiment 33. — Hold a piece of burning paper under a bell jar held mouth downward. (Figure 42.) Notice the air currents as indicated by the smoke. Paper soaked in a moderately strong solution of saltpeter and dried burns with a very smoky flame.

Experiment 34. — Fill a 500 cc. round-bottomed flask half full of water and place on a ringstand above a Bunsen burner. (Figure 43.) Stir in a little sawdust. Some of it should fall to the bottom of the flask. Gently heat the bottom of the flask. Notice the currents.

When the burning paper was held under the bell glass, and when the water was heated at the bottom of the flask, cur-

rents were seen to be developed. The heated and expanded air and water rose. Here again the heat was transferred by conduction, but it was helped by the upward movement of the heated water and air. These upward movements of the water and the air are known as *convection currents*. The efficiency of the hot water and hot air furnaces which heat our houses is due to the convection currents. We shall find later that if it were not for convection currents there would be no winds nor ocean currents.

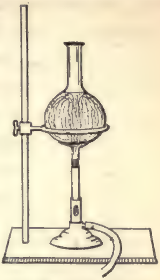


FIGURE 43

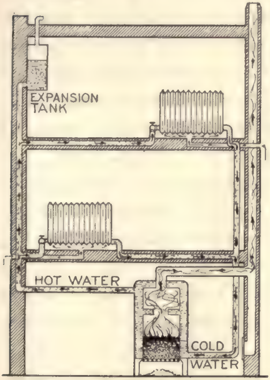


FIGURE 44. — HOT WATER FURNACE

As the water in the boiler begins to heat, convection currents are set up. Cold water, which is heavier, flows from the radiators down into the boiler and forces warmer water up into the radiators. As long as fire is maintained in the furnace, there is constant circulation. Since water expands under heat, an overflow tank must be provided to prevent explosion of the pipes or boiler.

Whether we heat a test tube of water from above or from below, the heat is carried by conduction from one molecule to another. But when we heat it from below, the process is hastened by convection currents.

If an incandescent lamp (Figure 45) is turned on and the hand held a little distance from the glass bulb, the hand will be warmed, although the glass bulb itself

(a poor conductor of heat) remains cool for a time. When the lamp was made, air was taken from the bulb, and so the white-hot filament is surrounded by almost empty space (*vacuum*). The heat, therefore, cannot travel to the hand by convection currents, because there is no air nor other substance in contact with the filament. The hand is not warmed by convection currents from the glass, because the bulb is still cool. The sensation of heat cannot be due to conduction, because the air which surrounds the bulb is not in contact with the hot filament. Besides, air is an even poorer conductor of heat than glass, and the glass itself does not become hot for some little time.

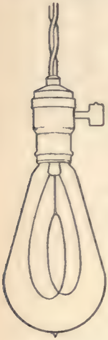


FIGURE 45

There must, therefore, be another mode of transferring heat besides conduction and convection. It also appears that in this method of transferring no material substance is necessary. This is shown by the fact that the hot filament is surrounded by an almost perfect vacuum. Astronomers tell us that there is no material medium between our atmosphere and the sun.

The heat of the sun travels to us with the tremendous speed of light, 186,000 miles a second, but does not warm the intervening space because there is no matter in it to be warmed. *Radiation* is the name given to this method of heat transference. If heat did not travel in this way, the earth would be uninhabitable. The conduction process is very slow when compared with radiation.

Conserving Heat. — Heat is so essential to life and happiness that it is often necessary to provide means for

preventing its escape. We build thick walls to our houses in order that the heat from our stoves and furnaces may not escape. We put on clothing in order that the heat of the body may be retained. Ovens of cookstoves are surrounded by air spaces and non-conducting materials so that the heat will not be lost. In fact there are scores of arrangements in every home for conserving heat.

Dark surfaces absorb heat more readily than light surfaces, and thus increase more rapidly in temperature. Light surfaces reflect heat, and absorb it very slowly. This is why we wear dark clothing in winter and light-colored clothing in summer. Dark surfaces not only absorb heat more readily but they radiate it more rapidly. Light surfaces are slow to heat up, and when they are heated up they are just as slow to radiate their heat. There is the same difference in these respects between smooth surfaces and rough surfaces as between light and dark surfaces.

REVOLVING DOORS
An arrangement to conserve heat.

The fireless cooker (Figure 46) is a device to save heat in cooking. It consists of two boxes, one within the other and separated from each other on all sides by a space of several inches. This space is filled with sawdust, ground cork, asbestos, or any other substance that is a poor conductor of heat. A tightly fitting cover is provided, containing similar non-conducting material. The food to be cooked is heated on the stove in a covered vessel, and this is placed within the cooker. Since the heat can escape only very slowly, the

food remains at nearly the boiling point for hours, and is thus cooked. In most cookers, heated pieces of soapstone are placed above and below the dish containing the food. Soapstone has a large capacity for heat. (Page 84.)

FIGURE 46. — DIAGRAM OF A FIRELESS COOKER

The fireless cooker can also be used as a refrigerator if the food is cooled before being placed in it or if ice is placed in it with the food. When the cooker is used as a refrigerator, the insulated walls are very slow to conduct the heat of the atmosphere to the cold food, just as they were slow to conduct the inside heat to the cooler surrounding atmosphere. The non-conducting character of the walls protects either way. For that reason the walls of a fireless cooker are similar to those of a refrigerator.

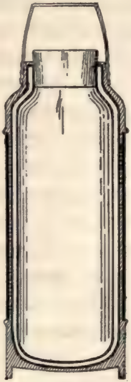


FIGURE 47. — DIAGRAM OF A THERMOS BOTTLE

Snow on the ground in winter prevents the heat from leaving the ground and the ground from being deeply frozen, just as the sawdust and other materials in the walls of the cooker prevent the heat from being conducted rapidly away from the cooker. That is one reason why farmers like a snowy winter.

The thermos bottle (Figure 47) is similar to the fireless cooker in principle. It consists of two glass bottles, one placed inside the other, sealed together at the neck. Before the bottles are sealed together the air between them is re-

moved. Heat, therefore, cannot pass from the inner bottle by conduction or convection. To retard the passage of radiant heat, the inner walls of the vacuum space are finished with bright reflecting surfaces.

Note to Students. — Both the Centigrade and the Fahrenheit scale are used in later discussions in this book. The student has been accustomed to the English or Fahrenheit scale in everyday life, and so occasionally the use of this scale prevents unnecessary confusion. On the other hand, the Centigrade scale is preferred in scientific work, and, like all the metric scales, is the rational system. It is, therefore, used frequently hereafter in order to familiarize students with it. In occasional discussions where one scale is used, *approximate* equivalents in the other scale are added in parentheses.

The following rules will be found useful in changing readings from one scale to the other:

To change Fahrenheit to Centigrade, subtract 32 from the number of degrees and multiply the remainder by $\frac{5}{9}$.

$$70° \text{ F.} = (70 - 32) \times \tfrac{5}{9} = 21\tfrac{1}{9}° \text{ C.}$$

To change Centigrade to Fahrenheit, divide the number of degrees by $\frac{5}{9}$ and add 32.

$$-10° \text{ C.} = (-10 \div \tfrac{5}{9}) + 32 = 14° \text{ F.}$$

SUMMARY

The sun is the source of the heat and light of the earth. Heat has the capacity to do work, and is therefore a form of energy. The sun is the source of the energy on the earth. If a body has the ability to do work without actually being at work, it is said to have potential energy; the energy of a body at work is called kinetic. There are different forms of energy, such as heat, light, electricity, gravitation, chemical energy, and mechanical energy. Energy can neither be created nor destroyed, but one form of energy may readily be changed into another. Heat causes most substances to

expand; withdrawal of heat causes most substances to contract.

Mass is the amount of matter in a body. Volume is the amount of space a body occupies. Density depends on the amount of matter in a given volume. Weight is the measure of the earth's attraction, or gravity, for any mass.

Heat is molecular energy. Sufficient heat will change solids to liquids and liquids to gases. The most common way of producing heat is by burning. Burning is a chemical process in which atoms of oxygen unite with atoms of fuel elements, such as carbon and hydrogen. Heat may also be produced by chemical, mechanical, or electrical action. The temperature to which a substance must be brought before it will burn is called its kindling temperature. Keeping fuel elements in a furnace at their kindling temperature and providing just the right oxygen supply are the two problems to be solved in saving fuel and abating the smoke nuisance. Fire can always be extinguished if the supply of air that reaches it can be shut off.

In gas, metal, and liquid thermometers, substances that expand and contract uniformily through ordinary temperatures are employed. The two most commonly used thermometer scales are the Centigrade and the Fahrenheit. Some substances require more heat than others to raise their temperatures. Water absorbs more heat than almost any other known substance. When a solid changes to a liquid or a liquid to a gas, a tremendous amount of heat is absorbed which does not raise the temperature. When the changes are reversed, this heat is given out.

Heat may be transferred by conduction, convection currents, and radiation. The principle of heat transference accounts for the efficiency of stoves and furnaces, as well as

of refrigerators. Fireless cookers, thermos bottles, revolving doors, refrigerators, etc., are devices to prevent rapid transference of heat.

Questions

When we say a body possesses energy, what do we mean? Give an example of each of the two kinds of energy.

You have used a great deal of energy to-day. Where did this energy come from?

What is the Law of the Conservation of Energy? What do we mean when we speak of "lost energy"?

Where have you seen the effects of expansion due to heat?

Explain the difference between mass, volume, density, and weight.

What is meant by saying that a substance is hot?

Why are iron and type-metal better suited for casting than copper and zinc?

Describe three ways of producing heat.

How are fires started?

What are the conditions necessary for obtaining all the heat possible from fuel?

Describe the different means you would employ in putting out fire.

France uses the Centigrade thermometer scale. If the temperature of Paris is reported as 25° C., what would the corresponding temperature be in the thermometer scale generally used in the United States?

Ponds near the Great Lakes freeze entirely over. Why do not the Great Lakes freeze?

Why would it not be as well to put ten pounds of ice-cold water into the refrigerator as ten pounds of ice?

In what ways is heat transferred?

Describe how you would prepare from the ordinary materials you have at hand a crude, inexpensive, fireless cooker.

CHAPTER V

THE ATMOSPHERE AND ITS SERVICE TO MAN

The Origin of the Atmosphere. — When the earth cooled from its original intensely hot condition, the substances

BLUE HILL OBSERVATORY, MILTON, MASSACHUSETTS

One of the first places in America where conditions of the upper atmosphere were studied.

which did not chemically combine to form liquids and solids, or which required a very low temperature for their consolidation, were left still in the gaseous state around the solid

core. This gaseous envelope, composed of these substances surrounding the earth, we call the *atmosphere*. Some of these gases are inert; that is, they do not readily form chemical combinations with other substances. Others have formed extensive combinations, but they exist in such large quantities that they were not thereby exhausted.

The Composition of the Air. — **Experiment 35.** — (Teacher's Experiment.) — Having rounded out a cavity in a small flat cork, cover the cavity and surface around it with a thin layer of plaster of Paris. After the plaster has set and become thoroughly dry, float the cork on a dish of water with the cavity side up. Place a piece of phosphorus as large as a pea in the cavity and carefully light it. (Figure 48.) (Great care must be taken in handling phosphorus, as it ignites at a low temperature and burns with great fierceness. It must always be cut and handled under water.)

FIGURE 48

As soon as the phosphorus is lighted, cover it with a wide-mouthed bottle. Be sure that the mouth of the bottle is kept slightly under water. The water will be found to rise in the bottle. The phosphorus soon ceases to burn. White fumes are formed, but these soon clear up. A clear gas is left in the bottle, but this cannot be air; for if it were, the phosphorus would have continued to burn in it, since it burns in air. If it were not for this property of not permitting phosphorus to burn, the gas left in the bottle could not be distinguished by ordinary means from air.

The gas fills more than three fourths of the bottle, so that more than three fourths of the air is composed of a gas which does not support combustion. This gas is called *nitrogen*. The other constituents of the air must also be transparent colorless gases, since the air is transparent and colorless. The most important of these is called *oxygen*. The phosphorus united with this and formed the white fumes. These fumes dissolved in the water, leaving the nitrogen.

Be careful to put the cork on which the phosphorus was burned in a place where it cannot cause a fire.

Although the air appears to be a simple gas and was so considered until the end of the eighteenth century, it has been shown to be a mixture of several different colorless gases. One of these, oxygen, supports combustion, as we have already learned; another, nitrogen, neither burns nor supports combustion. These two gases make up by far the greater part of the air about us, and occur in the proportion of about one part of oxygen to four parts of nitrogen. Carbon dioxide is also found in the air in the proportion of about 3 parts to 10,000. There are in addition very small quantities of several other gases, but these are not of sufficient importance to be studied here. Besides the gases, the air contains other matter, such as water vapor, dust particles, and microbes.

Almost all of us have had occasion to observe that if there is a slight leak of gas from the gas stove in the kitchen, the "smell of gas" will permeate the whole house. It makes no difference whether there are currents of air to carry the gas or not. Gases, whether heavy or light, mix readily with each other, or *diffuse*. As a rule, therefore, the proportion of oxygen, nitrogen, carbon dioxide, and other gases is the same for all places on the surface of the earth.

Oxygen is the most important part of the air to animals, for without it they could not live. They breathe in oxygen, and breathe out carbon dioxide. All the heat and energy animals have is due to their power of combining oxygen with carbon. Plants also have need of oxygen, but to a smaller degree than animals.

The nitrogen is needed to dilute the oxygen. If oxygen were undiluted, animals could not live; and a fire once started would burn up iron as readily as it now does wood. Plants and animals need nitrogen too, but it is of no use to

them as it occurs free in the air. Certain very low and minute forms of life known as bacteria have the power to take nitrogen from the air and to prepare it for the use of plants. The nitrogen must be chemically compounded with other substances before it can be used either by animals or plants as food.

Plants need carbon dioxide as much as animals need oxygen. The growth of a plant is due to the power it has of tearing apart the carbon dioxide by the help of the sun and of building the carbon into its structure. It returns the oxygen to the air to be used again by the animals and the plants. By far the greater part of plants is made from the carbon which they get from carbon dioxide.

Animals have not the bodily power of breaking down carbon dioxide to obtain oxygen from it; consequently they smother in this gas. Since men and other animals are constantly using up the oxygen in the surrounding atmosphere and are breathing out carbon dioxide, the rooms where they stay must be properly ventilated.

Carbon dioxide is heavier than air and has a tendency to accumulate in wells and unventilated mines. Workmen caught in this gas are smothered exactly as if by drowning. Frequently in coal-mine explosions so much carbon dioxide is formed that but little free oxygen remains; and so miners often escape an explosion only to be smothered by the carbon dioxide (choke damp, as they call it). Before going down into a well or cistern, careful workmen always lower a lighted candle to test for the presence of carbon dioxide. If this is present in large quantities the candle is extinguished.

In some places, such as Dog Grotto near Naples, Italy, and Death Gulch in Yellowstone Park, carbon dioxide is being steadily emitted from the ground. Since these places

are low and sheltered from the wind, the heavy gas accumulates in sufficient quantities to be fatal to animals that attempt to pass through them.

Moisture in the Air: Evaporation. — The atmosphere at all times and under all conditions contains some moisture. In the air of even the driest desert there is some water vapor. Plants and animals both need it. Were it not for the moisture in the air there would be no rain; and without rain no land life could exist. Thus the air, which contains oxygen and water vapor for both plants and animals, carbon dioxide for plants, and nitrogen to dilute the oxygen, is one of the most important life factors of the earth.

Experiment 36. — Carefully weigh a dish of water and put it in a convenient place where there is free access of air. After some hours weigh it again. What causes the change of weight? Try this experiment with a test tube, a watch crystal, and a wide-mouthed beaker, under various conditions and in various places.

When water is exposed to the air, it gradually disappears into the surrounding atmosphere. This process is called *evaporation*. Evaporation takes place only from the surface of a body of water. It may occur at any temperature; but since heat is absorbed in the process of evaporation (page 85), the more heat there is available, the more rapid will be the evaporation.

Evaporation must not be confused with boiling. Heat is absorbed in both processes; but boiling takes place only at a *definite* temperature and goes on *inside* the liquid.

If the water surface is large and the temperature high, there is a large amount of evaporation and the water rapidly rises into the air. In the tropics the evaporation from the

water surface amounts to perhaps eight feet per year. This means that the energy of the sun evaporates about five hundred pounds of water from every square foot of the surface every year. In the polar latitudes the amount of evaporation is perhaps a tenth of that in the tropics.

From every water surface on the globe, however, a large amount of water is evaporated each year.

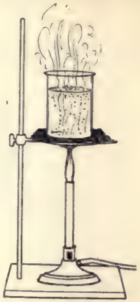


FIGURE 49. — BOILING ACCOMPANIED BY RAPID EVAPORATION

Effect of Temperature on the Capacity of the Air to Hold Moisture. — **Experiment 37.** — Take a liter flask and put into it just sufficient water to make a thin film on the inside of the flask when shaken around. Now warm the flask gently, never bringing its temperature near to the boiling point, until the water disappears from the inside and the flask appears to be perfectly dry. Having tightly corked the flask, allow it to cool. The flask appears dry when warm and on account of having been corked tightly no moisture could have entered it. The air in the flask was perfectly transparent both before and after heating. The film of water around the inside of the flask was taken up by the air when it was warmed but the moisture reappeared when the flask was cooled.

Experiment 38. — Fill a bright tin dish or glass beaker with ice water and after carefully wiping the outside allow it to stand for some time in a warm room. Can water go through the sides of the dish? Does the outside of the dish remain dry? If water collects upon it, from where does the water come? See if the same results will follow if the water within the dish is as warm as or warmer than the air in the room.

Experiment 39. — Partially fill a dish or beaker like that in the previous experiment with water having a temperature a little warmer than that of the room. Gradually add pieces of ice, con-

tinually stirring with a chemical thermometer. Note the temperature at which a mist begins to appear upon the outside of the dish. When the mist has appeared, add no more ice but stir until the mist begins to disappear. Note this temperature. Take the average of these two temperatures. This average is probably the temperature at which the mist really began to form. This temperature is called the *dew point.*

When we wish to dry clothes, we place them in a warm room or in the sunshine. Soon we find that the water has left the clothes. It must have gone into the air. It would thus appear that when the temperature of the air is raised, it has the capacity of taking up more moisture than when it is cold. This was seen in Experiment 37. Both Experiments 38 and 39 showed that when air is sufficiently cooled, it begins to deposit moisture. Experiment 39 showed the temperature at which the deposition began. This was the dew point for that time and place.

This property that air has of taking up a large amount of moisture when heated and of giving it out when cooled is the cause of our clouds and rain.

Humidity. — The condition of the air as regards the moisture it holds is called its *humidity.* The amount of vapor present in the air is spoken of as its *absolute* humidity. The amount of vapor in the air as compared with the amount the air would contain if it had all it could hold is known as its *relative* humidity. For example, air at 80° F. is capable of holding almost 11 grains of water vapor per cubic foot. Suppose it actually contains 6 grains of water vapor per cubic foot. It will be loaded then with about $\frac{6}{11}$, or a little more than $\frac{1}{2}$ of the moisture it would contain if it were *saturated* (that is, had all the moisture it could hold). This fraction represents the relative humidity of the atmosphere.

By determining the dew point as was done in Experiment 39 and comparing this with tables which have been prepared by meteorologists from many observations, relative humidity can always be approximately determined. An instrument

STRATO-CUMULUS CLOUDS
Typical low level clouds, indicating showers.

for determining the relative humidity of the air is called a hygrometer (Figure 50).

To be considered moist, air must contain at least more than half the amount of moisture it is capable of carrying. If air contains much more than half the moisture it can carry, its humidity is said to be high. When air which has a high humidity is cooled it soon reaches a point of temperature where it is saturated (the dew point). If the temperature falls below this point, the air must deposit some of its mois-

ture. It is important not to think of the dew point as a fixed point of temperature, like that of freezing or boiling. The dew point depends not only upon the temperature of the air but also upon the amount of vapor in the air.

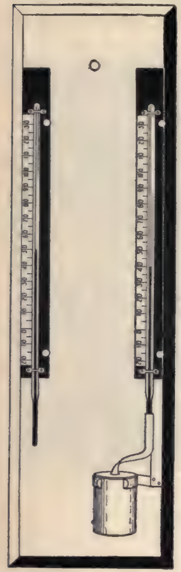


FIGURE 50.—AN HYGROMETER

Condensation of Moisture of the Air. — Moisture of the air may condense into little droplets high above the earth's surface, making clouds. If these droplets form near the surface of the earth, the cloud of moisture is called *fog*. If it collects on objects on or near the ground, it is called *dew*. When droplets in the clouds become so large that they are too heavy to remain suspended in the air, they fall as *rain*. Rain and dew can form only when the dew point is higher than the freezing point. When the dew point falls below the freezing point, moisture of the atmosphere condenses as *snow, sleet,* or *frost*. Thus a fall of snow on a mountain is sometimes accompanied by rain in the valley.

Cooling by Evaporation. — Experiment 40. — Mark with a rubber band the height of the water column in an air thermometer (Figure 51). Let fall a few drops of ether or alcohol on the bulb, and notice the change in the height of the column. Place a little ether on the back of the hand. What kind of sensation does it give? (Be careful to use only a few drops of ether, as it is bad to breathe it too freely.)

When the ether was dropped on the air thermometer bulb it evaporated and the water column rose just as it did

FOG

A low cloud formed near the surface of the earth.

in Experiment 27. Ether is one of a number of liquids, such as gasoline and alcohol, that evaporate more rapidly than water. The more rapidly a liquid evaporates, the more rapidly it takes up heat from its surroundings. That is why ether feels colder to the hand than water. In many places, at the present time, advantage is taken of rapid evaporation in the construction of ice and cold-storage plants.

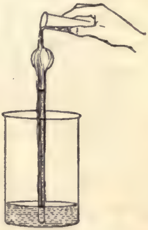


FIGURE 51

The canvas desert water-bag (Figure 52) illustrates a simple application of the principle of cooling by evaporation. The water seeps very slowly through the bag, and the evaporation of this seeping water absorbs the heat from the water in the bag and keeps it cool enough to refresh the thirsty traveler. Nature

provides for keeping the human body and the bodies of some other animals at the right temperature by this process of evaporation. The warmer the healthy body gets the more it perspires, and the evaporation of the perspiration keeps down the temperature. In case of fever, the pores of the body close up, perspiration ceases, and the temperature immediately rises. The physician often has to use ice packs to do the work of normal evaporation until perspiration resumes.

FIGURE 52. — DESERT WATER BAG

Plants are also kept cool by the evaporation of water which exudes from their leaves. This is called *transpiration.*

Humidity and Comfort. — The humidity of the air has much to do with our bodily comfort. In quiet warm air, nearly saturated with moisture, the perspiration cannot readily evaporate and cool the body. Thus a temperature of 80° F. with a high relative humidity may be more uncomfortable than a temperature of 95° F. with a low relative humidity. On a humid day the perspiration that evaporates brings the air that is near the body closer to the saturation point, and we fan ourselves to move it away and to allow the less moist air to take its place. Any breeze gives relief because it keeps changing the air around the body. An electric fan, although it in no way cools the air, helps evaporate the perspiration by keeping the air in motion. Crowded rooms often become " close " because of a

layer of densely humid air around the crowd that results from the moisture of the breath and the evaporation of perspiration. Such rooms may often be rendered quite comfortable by opening more windows or by starting an electric fan, even when there is no way of lowering the temperature of the atmosphere.

In cold weather when the temperature of the body is considerably higher than that of the surrounding atmosphere, moist air chills us. This is because moist air is a better conductor of heat than dry air and readily absorbs heat from the body.

The air in most living rooms in winter is too dry. Since the air in the room has been heated it is capable of holding more moisture than the outdoor air. Unless water is supplied to it, its relative humidity is much lower than that of the air outside. In some heated rooms in winter the air is really drier than the air over the deserts. In this dry air the perspiration evaporates very rapidly and makes us cold even though the temperature of the room is high. This hot, dry air is injurious to the eyes, irritating to the nerves, harmful to the membranes of the nose and throat, and conducive to colds. Such air dries the moisture out of the glue in the furniture, often warps woodwork, and tends to shrivel up everything in the room.

FIGURE 53. — HOMEMADE HUMIDIFIER

In the interest, therefore, of the conservation of health, as well as of fuel and of furniture, open vessels of water (humidifiers) should be kept on stoves, radiators, or registers, in order to keep the air of living rooms moist. Hanging up cloths, the ends of which are in pails of water, will serve the purpose even better, because they increase the surface from which evaporation takes place and thus furnish more water to the air in less time. (Figure 53.) There are many patented devices for humidifying, but the principle on which all of them are constructed is the same as that of the homemade humidifier. A temperature of between 65° F. and 70° F. will make a room comfortable if there is sufficient moisture in the air.

Weight of Air. — **Experiment 41.** — Into a five-pint bottle insert a tightly fitting rubber stopper through which a glass tube extends.

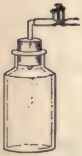


FIGURE 54

To the outer end of the glass tube tightly fit a thick-walled rubber tube of sufficient length for the attachment of an air pump. Put a Hoffman's screw upon the rubber tube. (Figure 54.) See that all connections are air-tight. Weigh carefully the apparatus as thus arranged. Now attach the rubber tube to an air pump and extract the air from the bottle. When all the air that can be exhausted has been removed, close the rubber tube tightly with the Hoffman's screw and weigh again. Unclamp the Hoffman's screw and allow the air to enter the bottle. The weight should be now the same as at first. Or, instead of weighing a bottle of air, weigh an incandescent light bulb. Make a hole in it with a blowpipe and weigh again. Is the weight now the same as before?

We have found by the previous experiment that air has weight. With the apparatus used it was impossible to tell exactly the weight of the air extracted or to determine the weight of a definite volume of the air. If we had been

able to do this, we should have found that on an average day, at sea level, the weight of a liter, a little more than a quart, of air, is about 1.2 grams. Twelve cu. ft. weigh about one pound. The air extends to so great a height that although very light, the weight of so great a mass of it is enormous.

Expansion of Air when Heated. — Air expands very much when heated, as was seen in Experiment 18. It is found that if air at freezing is heated to the temperature of boiling water, it will expand about $\frac{4}{11}$ of its volume. The force with which air expands is so great that sometimes when buildings are on fire and there is no opening for the confined air to escape, the walls are blown out or the roof blown off by the expansion of the hot air, and great injury is done to those fighting the fire. That air expands upon being heated is readily seen when an air-filled toy balloon is brought from the cold outer air into a hot room, — the covering begins at once to tighten and the balloon to swell.

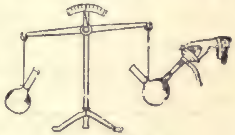


FIGURE 55

Weight of Air as Affected by Heat and Cold. — **Experiment 42.**— Take two open flasks of nearly the same weight and capacity and balance in as nearly a vertical position as possible at the ends of the arms of a beam balance. Bring the flame of a Bunsen burner to the upper side of the bulb of one of the flasks so that the hot air currents that are generated will have no upward push on the flask. (Figure 55.) Do not allow the hot air to get under the flask. What is the effect?

As the previous experiment shows, and as we should expect from the fact that air has been found to expand when heated, hot air is lighter than cold air. A liter of air at freezing under ordinary pressure weighs about 1.293

grams, but at the temperature of boiling water it weighs only about .946 grams. So a volume of cold air, being heavier, will exert more pressure at the surface of the earth than an equal volume of hot air.

As air is a gas whose particles can move freely among themselves we should expect that a heavier column of cold air would sink down and distribute itself along the surface under surrounding lighter air, just as a column of water falls when its supports are withdrawn and forces up the lighter air which surrounds it.

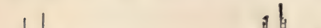


FIGURE 56. — HOT-AIR FURNACE

Cold air presses in from the outside and causes the hot air to rise through the pipes and registers.

A similar action is seen when water is poured upon oil: the water sinks to the bottom and forces the oil to rise. Thus if air is heated at any place, we should expect that there would be a rising current of hot air and a current of colder air creeping in to take its place. The winds of the earth are due to this property of air. It is this tendency of heated air to rise that makes hot-air furnaces useful for heating houses (Figure 56). Valleys are generally colder than the surrounding hillsides, so that delicate crops can be grown successfully on the hillsides although those in the valley may be frostbitten.

Experiment 43. — Use a convection apparatus or take a tight chalk box and in two places on the top punch holes in a circle not quite as large as the bottom of a lamp chimney. Place a small lighted candle at the center of one of the circles of holes and a lamp chimney, tightly sealed to the box, about each circle. Hold a smoking piece of paper above the chimney which does not inclose the candle. (If a pane of glass is put into one of the vertical sides of the box, better observations can be made.) (Figure 57.) What happens? Put out the candle and carefully heat the chimney with a Bunsen burner. Is there the same action as before? Why is it that sparks rise from a fire? What is meant by the *draft* of a stove? Why in order to ventilate a room is it best to open a window at the top and bottom?

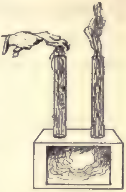


FIGURE 57

The refrigerator illustrates the effect of temperature upon the circulation of air (Figure 58). The coldest air in the refrigerator is nearest the ice. This being heaviest naturally falls. The farther away from the ice it gets the warmer and therefore the lighter it becomes. The falling current of cold air pushes the warmer air up through the compartments on the opposite side and back to the ice again, thus making a continuous circulation.

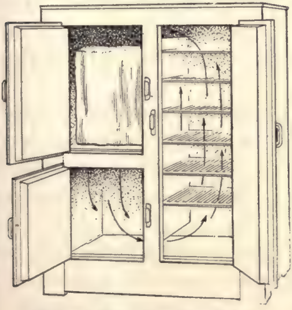


FIGURE 58. — REFRIGERATOR
Diagram illustrating circulation of air when the doors are closed.

It is not generally recognized that an electric fan may be made just as useful in winter as in summer. The warm air in a room tends to rise to the upper

part of the room. A fan placed as near the ceiling as possible will force this warm air down to a lower level, and in this way make all parts of the room more nearly uniform in temperature. This often proves an effective remedy for cold floors. In winter the air near windowpanes is often reduced below its dew point and films of ice form inside the panes. This can be prevented by using a fan to keep a fresh supply of warm air moving across the glass. Most merchants have learned to apply this principle in keeping their display windows clear in severe weather.

Ventilation. — The movement of air caused by its heating and cooling provides a means for ventilating rooms and buildings in winter. In warm weather we do not have to be persuaded to keep our windows open; but when winter comes, many people become careless about ventilating their houses. Health requires that a person have pure, normally moist air to breathe. Sleeping rooms as well as living rooms must be constantly supplied with outdoor air. The old notion that night air was harmful is contrary to the truth. Fresh air day and night is essential to the maintenance of health.

Several ways have been devised for ventilating large buildings and for maintaining proper air conditions, but these require mechanical means for driving or for drawing the air into the building, and are not suitable for dwellings.

Houses heated by hot-air furnaces in which the cold air flue is properly cared for (Figure 56) need only a provision for the exit of hot, stale air. An open grate or fireplace in which there is a fire, or a window in each room opened slightly at the top will accomplish this.

Houses heated by steam or by hot water sometimes have special arrangements for ventilating (Figure 44). In some houses the radiators are placed in open air ducts beneath the floor. The fresh air enters these ducts from outdoors, is warmed as it passes the radiators, and rises through registers in the floor to warm the rooms. The cold air from the outside keeps pushing the warmed air up out of the ducts and flowing in to take its place. Thus a continuous circulation is maintained over the radiators into the rooms. The same arrangements must be made for the exit of stale, hot air as are made when the hot air furnace is used.

Many houses, however, cannot be ventilated except through the windows and doors. It is most important to learn how this may be done effectively. One simple method is to cut a narrow board into a length that exactly equals the width of the window sash. Raise the lower sash, fit the board into the running groove, and close the sash down on it. This leaves an open space between the upper and the lower sash through which fresh air may enter. If the upper sash be pulled down to leave an opening of an inch or so at the top, an exit for the stale air is provided.

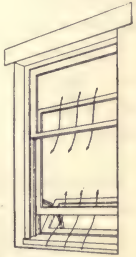


FIGURE 59. — ADJUSTABLE VENTILATOR

According to another method, a board ten or twelve inches wide is cut just long enough to reach across the inside of the casement. This board is placed lengthwise on the inside sill with its ends fastened to the sides of the casement. When the lower sash is raised, the board deflects the current of cold air upward so as to prevent a direct draft. In this case the opening between the sashes serves

as an exit for the stale air, and the upper sash does not have to be lowered. In severe weather this is more successful than the first method. An adjustable ventilator of this kind is shown in Figure 59.

But the cloth screen is probably the most successful means of steady ventilation in severe weather. For houses that have only casement windows it is about the only method. Make a screen frame that fits snugly into the casement. Cut a piece of muslin to fit the frame and tack it on just as you would wire screening, being sure to stretch the muslin tight as you put it on the frame. With this in place, the casement window may be opened wide in the most severe weather without any danger of direct drafts but with assurance of fresh air supply. The cloth screen may be adapted to the sash window, and it is especially useful on stormy nights because it makes it possible to keep a sleeping room window wide open all night.

Whatever method of ventilation is used, the windows and doors should be opened once or twice *every day* so that cold fresh air may blow in and flush out the stale air of the rooms. Fresh air and sunlight are man's cheapest doctors.

Pressure of the Atmosphere. — **Experiment 44.** — If a tin can with a tightly fitting screw cap can be easily procured, boil a little water in it, having the screw cap open so that the steam can readily escape. While the water is still strongly boiling, quickly remove the can from the heat and tighten the cap. Be sure not to tighten the cap before removing the can entirely from the heat. Set the tin thus closed upon the desk and observe. What happens as the steam condenses? Why?

Experiment 45. — By means of an air pump exhaust the air from a pair of Magdeburg hemispheres. (Figure 60.) Now try to pull the hemispheres apart.

FIGURE 60

It cannot be done as easily as before the air was exhausted. Why?

Experiment 46. — Fill a glass tumbler even full of water and press upon it a piece of writing paper. (Figure 61.) Be sure that the paper fits smoothly to the rim of the tumbler. Take the tumbler by its base and carefully invert it over a pan. Does the water fall out? If not, why not? While the tumbler is in the inverted position, insert the point of a pencil between the paper and the rim of the tumbler. What happens?

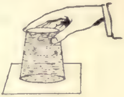


FIGURE 61

Experiment 47. — Fill a bottle with clean water and fit it tightly with a rubber stopper having two holes in it. Plug one of the holes tightly with a glass tube one end of which has been closed by heating in a Bunsen burner. Through the other hole put an open glass tube 10 to 15 cm. long. See that both tubes fit tightly in the stopper and that the stopper fits tightly in the bottle. (Figure 62.) Now attempt to "suck" the water out of the bottle through the open tube. Does it come out freely? Pull out the glass plug. Does it come out any better? If so, why?

FIGURE 62

Anything that has weight must exert pressure upon the surface upon which it rests. The air has been found to have weight, and therefore it must exert pressure at the surface of the earth. It is a gas; and since the particles of a gas easily move over one another, this pressure must be exerted equally in all directions.

We do not feel the pressure of the atmosphere because the pressure inside us balances the pressure from without. If two eggshells, with their contents removed — one of them with the holes left in it, and the other completely sealed — should be sunk to a considerable depth in water, which one would be crushed by the pressure of the water, and which would not? This illustrates why objects on the surface of the earth are not crushed by the pressure of the air.

In the preceding experiments atmospheric pressure accounted for the various things that happened. When the steam in the can cooled, it condensed and occupied less space. The pressure of the atmosphere from the outside, therefore, pushed the sides inward. With the atmospheric pressure lessened inside the Magdeburg hemispheres, the full atmospheric pressure on the outside held them together. The inverted glass kept the atmosphere from pressing down on the surface of the water immediately under it. The upward pressure of the atmosphere on the paper was greater than the downward pressure of the water. When you withdrew air from the glass tube, the pressure of the atmosphere on the surface of the water forced the water up into the tube to take the place of the air that had escaped.

Variation in pressure due to heating and cooling of air explains circulation and drafts. A column of cold air is denser and therefore heavier than a corresponding column of warm air. The cold air, therefore, presses the warm air up, and takes its place below.

Measuring Atmospheric Pressure. — **Experiment 48.** — (Teacher's Experiment.) — Take a thick-walled glass tube of about ½ cm. bore and 80 cm. length. Close it at one end. Fill the tube with mercury. (Be sure to place the closed end of the tube in a large vessel so as not to waste the mercury if you spill it.) Place the thumb tightly over the open end of the tube and invert it in a vessel of mercury. If you are at or near sea level, the mercury column will drop to a height of about 75 cm. (about 30 inches) and will stand there. This is known as Torricelli's Experiment, because Torricelli first performed it and explained it.

The space above the mercury is without air, and therefore no atmospheric pressure is exerted at the top of the column of mercury. The column of mercury is pressing

down on the surface of the mercury in the vessel. The atmosphere is also pressing down on the surface of the mercury in the vessel. The one pressure balances the other.

It makes no difference what the diameter of the column of mercury is, it will stand at just the same height. If then we weigh a column of mercury an inch square at the base and thirty inches tall, we can find what the approximate pressure of the earth's atmosphere is on every square inch of the earth's surface at sea level. Such a column weighs about fifteen pounds. Therefore the pressure of the atmosphere is about fifteen pounds to the square inch at sea level.

Experiment 49. — (Teacher's Experiment.) —Take a thick-walled glass tube of about $\frac{1}{2}$ cm. bore and about 80 cm. length and slip tightly over the end of it about 10 cm. of a thick-walled flexible rubber tube 30 cm. in length. Firmly secure the rubber tube to the glass tube by winding tightly around them many turns of string, making it impossible for the rubber tube to slip or admit air. Completely close the rubber tube with a Hoffman's screw just beyond the place where it leaves the glass tube. Placing this closed end in a large dish so as not to waste any mercury, fill the glass tube with mercury. Place the thumb over the open end of the tube and invert it in a cup of mercury. If the connections were made tight, the mercury will not fall far below the end of the glass tube. The air pressure keeps the mercury up. This is a simple form of barometer.

FIGURE 63

While the tube is still standing in the mercury cup take another glass tube similar to the first and attach it to the open end of the rubber tube in the same way as the first was attached. Place the free end of this tube in a dish of colored water and gradually open the Hoffman's screw. (Figure 63.) The water rises in the tube. Why? What is meant by sucking water up a tube?

Machines that Make Use of Air Pressure. — Lift Pump. — The ordinary lift pump (Figure 64) is a machine which

utilizes air pressure for "lifting" water. When the piston of the pump is raised from the bottom of the cylinder a partial vacuum is created in the cylinder. The air pressure on the water in the cistern forces the water up the pipe and through the valve B into the cylinder. When the piston descends the valve B in the bottom of the cylinder is closed by the weight of the water and the valve A in the piston opens allowing the water to flow through to the upper side of the piston. As the piston is once more raised the valve A closes and the water above the piston is lifted and flows out the spout. Air pressure again forces more water up the pipe and through the valve B into the cylinder. The water continues to rise into the cylinder and to be lifted out as long as the pump is worked.

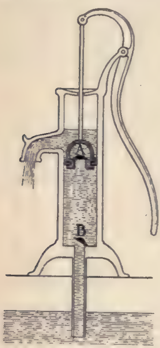


FIGURE 64. — DIAGRAM OF A LIFT PUMP

Lift pumps were in use for 2000 years before any one successfully explained their operation. Galileo observed that in the best lift pumps the water could not be made to rise higher than 32 feet, but he died without being able to explain why. When Torricelli, his pupil and friend, performed the experiment with the mercury tube, and found that atmospheric pressure would support a column of mercury about 30 inches high in a vacuum, he explained what had puzzled Galileo. Since mercury is about thirteen and one-half times as heavy as water, the pressure of the atmosphere would support a column of water thirteen and one-half times as high as the column of mercury. In a perfect vacuum, therefore, the pressure of the atmosphere would

support a column of water about 34 feet high. But since it is impossible to create a perfect vacuum with the piston and valves, water never rises as high as this in a lift pump. In practice the average limit is about 27 feet.

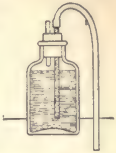


FIGURE 65

The Siphon. — **Experiment 50.** — Fill an eight-ounce bottle with clean water and fit it tightly with a two-holed rubber stopper. Through one of the holes in the stopper insert a tightly fitting glass tube, which reaches nearly to the bottom of the bottle and extends an inch or two above the stopper. Attach to this glass tube a clean rubber tube which is long enough to reach below the bottom of the bottle. Fit a sealed glass tube so that it can be readily inserted in the open hole of the stopper. (Figure 65.)

A GREAT SIPHON IN THE LOS ANGELES AQUEDUCT

"Suck" water out of the end of the rubber tube hanging below the bottom of the bottle. As soon as the water begins to flow, withdraw the mouth without raising the tube. The water will still continue to flow. Insert the sealed glass tube in the open hole of the stopper. The water stops flowing. Pull out the glass plug. The water begins to

flow again. If the water, once started, is allowed to flow, it will empty the bottle to the end of the glass tube. Any bent tube arranged in this way, with one arm longer than the other, is called a *siphon.*

In Experiment 50, the water in the siphon was pressed outward from the bottle by atmospheric pressure minus the weight of the column of water in the short arm. It was pressed toward the inside of the bottle by atmospheric pressure minus the weight of the column of water in the long arm. The atmospheric pressure was practically the same in both cases, but the weight of the water column in the short arm was less than that of the water column in the long arm. The pressure acting outward was therefore greater than that acting inward and the water flowed out of the bottle. The siphon continued to flow as long as the inequality of pressure was maintained. When the atmospheric pressure was shut off by the insertion of the sealed glass tube, the water of course stopped flowing.

Vacuum Cleaners. — **Experiment 51.** — Allow a beam of light to enter a darkened room through a small hole in a curtain. Note as carefully as you can the different things in the air that the beam of light reveals.

In the preceding experiment we observed that the air contained something more than the gases and moisture which we have learned are in it. There are many solid particles floating in the air. There were little shreds of cloth and paper, pieces of dust and soot, and many other things. The beam of light, however, did not reveal everything that was floating in the air. There were many living organisms, tiny plants (*bacteria*), too small to be seen except by the aid of a high-power microscope.

These minute living things are scattered all through the

air, sometimes living on dust particles and sometimes unattached to anything. Only a few of the bacteria are harmful, and they are usually not very abundant. Sunlight kills most of them in a short time, but moisture and darkness furnish conditions favorable for them. They are

Courtesy of Elgin Sales Corporation

A MODERN STREET SWEEPER

The left end is the forward end. This machine sprinkles, sweeps, and collects the sweepings. The operator is working the lever which empties the machine.

particularly abundant in the dust of the street and wherever foul refuse accumulates. When they get into a house they settle and multiply rapidly if they happen to light upon a warm, moist place where the sunshine is not too bright. Ordinary dusting and sweeping simply scatter them about and keep them floating in the air for hours, for us to

breathe. Carpet sweepers and oiled dust cloths do much to prevent stirring up the dust and bacteria, but vacuum cleaners are even more effective.

The vacuum cleaner is a device to utilize air pressure for cleaning. By means of a pump or a rapidly rotating fan, the air in the machine is exhausted. Atmospheric pressure forces the air up through the mouth of the machine, driving the dust and dirt particles with it. This dust-laden air passes into a closely woven bag, which sifts out and collects most of the dust. By using this machine no dust is scattered through the air of the room.

Vacuum cleaners have also been invented for street cleaning, but outdoor conditions make them less satisfactory than vacuum cleaners for the household. Most cities depend upon washing or sweeping to keep the streets clean. Where sweepers are used, they should always be preceded by sprinklers in order to keep down as much of the dust as possible.

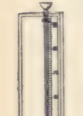


FIGURE 66

Decrease of Volume Due to Pressure. — **Experiment 52.** — In a Mariotte's tube (Figure 66) cause about a centimeter of mercury in the short arm to balance the same amount in the long arm. The pressure inside the short tube will then be equal to that outside the long tube and will be that of the air upon the day of the experiment. The short arm will now be sealed with mercury so that no air can get in or out. Pour mercury into the long arm. The air in the short arm will be gradually compressed and will occupy less and less space. If we remember that the pressure upon the air in the short arm is the air pressure of the day plus the pressure of the mercury column in the long arm that rises above the mercury level in the short arm, we can show by careful measurement that the volume of the air decreases just as the pressure increases.

As was seen in Experiment 9, the volume of air can be very much decreased by pressure. It cannot be told from this experiment whether the volume of the gas decreases as the pressure increases or whether it decreases much more rapidly when first pressed upon than afterward. This can be best shown by the use of the Mariotte's tube as in Experiment 52. But if the bicycle pump is a good one, it will answer the question of the rate of decrease quite accurately. It is found that *the volume decreases directly as the pressure increases.*

Increase of Pressure Due to Decrease of Volume.—When a given volume of air is compressed it exerts more pressure. If air is compressed to one third its original space, it will exert three times as much pressure as it did before. When the pressure is removed it regains its original volume. A puncture in an inflated automobile tire shows how rapidly and forcibly air will expand from its greater density under pressure to the density of the surrounding atmosphere. These properties of compressibility and expansion which air has, in common with other gases, have many practical applications. One of the most familiar applications is in the air pumps of garages. Compressed air is also used to apply brakes on street cars, steam engines, and railway coaches. It is used to blow whistles, to ventilate mines and large buildings, and to operate heavy hammers, rock drills, and riveting machines.

The force pump illustrates a use of compressed air. An "air cushion" is used to deliver a steady stream of water to a point higher than the mouth of the pump. In the force pump, the water rises into the cylinder when the piston is raised, exactly as in the ordinary lifting pump. The piston

has no valve, and so when it descends it forces the water out through the pipe (*E*) (Figure 67) into the air chamber (*D*), thus compressing the air in it. The valve (*C*) keeps the water from running back when the piston is lifted. While the piston is ascending, the pressure of the air cushion (*D*) forces a steady stream through the pipe (*A*) to the tank above.

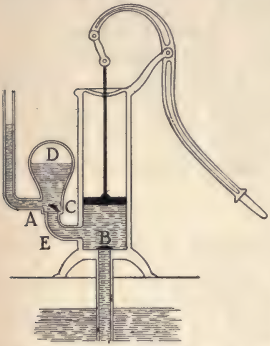


FIGURE 67. — DIAGRAM OF A FORCE PUMP

The force pump is sometimes used to fill tanks in attics of farmhouses so as to provide private water-systems. The principle of the force pump is used in the more complicated pumps for water-works, fire engines, and mines.

Heat Produced by Compression and Cooling Produced by Expansion. — **Experiment 53.** — Have a five-pint glass bottle fitted with a two-hole rubber stopper. Pass through the holes in the stopper a chemical or air thermometer and a short glass tube. The lower end of the glass tube which extends into the bottle should be kept as far as possible away from the bulb of the thermometer, so that when the air is exhausted or allowed to enter the bottle there will be no movement of the air near the bulb of the thermometer. The end of the column of the thermometer must be visible above the stopper. (Figure 68.)

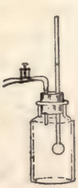


FIGURE 68

Attach the glass tube to an air pump by means of a thick-walled rubber tube. Note the temperature of the thermometer within the bottle and also of the air outside. Quickly exhaust the air

from the bottle, carefully noting the action of the thermometer. See that the temperature of the air in the room does not change during the experiment. Allow the air quickly to enter the bottle and note the action of the thermometer. The temperature inside the bottle changes as the air is quickly exhausted, or as it is allowed to enter the bottle again and thus to increase the density of the air in the bottle.

It has been found that when air or any other gas expands, it absorbs heat and cools its surroundings; and when it is compressed, it yields heat and warms its surroundings. This heating and cooling by changes in the density of gas is called *adiabatic* heating or cooling. It is taken advantage of in the manufacture of liquid air and is the same principle which is utilized in cold-storage plants. This property of air has much to do with developing our wind circulation and storms.

The heating effect of compressing air can be well seen when an automobile tire is filled. No matter how well the piston of the pump may be oiled, as the density of the air in the tire begins to increase, the pump will grow warm rapidly. This rapid heating cannot be due to friction, as the pump is not being worked any more swiftly than at first. It is due to the greater compression of the air. As this compression increases, the heating increases, the effect of friction in a well-oiled pump being of small value.

Pressure and the Boiling Point. — Experiment 54. — (Teacher's Experiment.) — Fill a strong 500 cc. round-bottomed flask about one third full of water. Boil the water. While the water is briskly boiling, remove the flask from the heat, quickly close its mouth with a rubber stopper, and invert it in a ringstand. (Figure 69.) (Be sure not to insert the stopper until the flask is fully removed from the heat.) Pour cold water upon the flask. The water will again begin to boil.

In this experiment the steam was condensed by the sudden lowering of the temperature. The condensation of the steam relieved the pressure on the surface of the water, and the water in the flask began to boil again although it had become considerably cooler than when it was first boiled. Thus it appears that if the pressure on the surface of water is decreased, the water will boil at a lower temperature. Advantage is taken of this in condensing milks and sirups. The liquids are heated under hoods from which air is continuously exhausted. The water is thus "boiled away" at so low a temperature that there is no danger of scorching the sirup or the milk.

FIGURE 69

On high mountains where the air pressure is considerably less than at sea level, water boils at less than 100° C. In Denver it boils at 95° C.; in the City of Mexico, at 92° C.; in Quito, Ecuador, at 90° C. Because water boils in such places at a lower temperature, it takes longer to boil food until

PRESSURE COOKER

it is "done." To hasten the process of cooking by boiling in high altitudes, pressure cookers are often used. The high pressure developed by keeping the steam imprisoned raises the boiling point of the water within. The contents of the cooker may thus be brought to a temperature of 170° C. or even more. This intense heat reduces the time of cooking and thus saves fuel.

The Manufacture of Ice; Cold Storage. — We saw in Experiment 53 that when air was compressed it gave up heat and warmed its surroundings. When pressure was removed, the air absorbed heat and cooled its surroundings. Other gases act in the same way. Water vapor, for example, may be compressed until it gives up so much heat that it returns to the liquid state.

Ammonia is a gas that at ordinary temperatures is easily condensed by pressure into a liquid. (This liquid must not be confused with the aqua ammonia of our kitchens, which is simply water that has absorbed ammonia gas.) When the pressure is removed, the liquid ammonia quickly returns to the gaseous state, and in so doing it absorbs much heat.

Figure 70 shows the essential construction of an ice plant. The pump (*A*) compresses the ammonia gas into the pipes at (*B*). The pressure condenses the gas into liquid, and the cold running water absorbs the heat given out in the process. The liquid thus cooled is allowed to run very slowly through the valve (*C*), into the pipes at (*D*). The valves in the pump (*A*) are so arranged that while the pump increases the pressure in the pipes at (*B*) it decreases the pressure in the pipes at (*D*). Because of the low pressure in the pipes (*D*), the liquid ammonia evapo-

rates; that is, returns to the gaseous state. In so doing it absorbs heat very rapidly from its surroundings (page 105). The gaseous ammonia returns to (*A*) from the pipes (*D*) because of the exhaust action of the pump. It is again compressed into the pipes at (*B*). Thus the action continues without loss of ammonia.

The ammonia pipes pass through the brine into which cans of water have been lowered. Brine is used to surround the ice cans because it does not freeze unless its

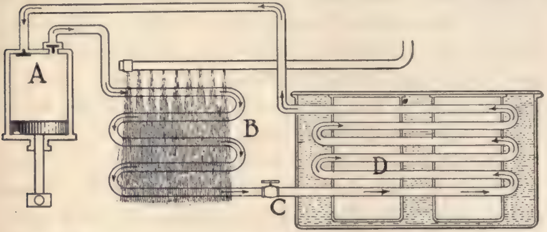


FIGURE 70. — DIAGRAM SHOWING ESSENTIAL CONSTRUCTION OF AN ICE PLANT

temperature is reduced many degrees below the temperature at which pure water freezes. The evaporation of the ammonia in the pipes reduces the temperature of the brine so low that the water in the cans is frozen, but the brine remains liquid, so that the cans may be easily removed.

In cold storage plants the pipes (*D*) are placed in the cold storage rooms to reduce the temperature of the air in the rooms, just as they reduce the temperature of the brine in the ice plant.

The Barometer. — On account of the movements of the air due to heating and cooling and to other causes, the

pressure of the atmosphere at any place on the earth's surface is liable to change. Since measurement of atmospheric pressure is of great importance in the study of atmospheric conditions, it is necessary to have an instrument by which changes in pressure can be readily measured. An instrument designed for this purpose is called a *barometer*. There are two kinds of barometers in common use, the *mercurial* and the *aneroid*.

If the tube used in Torricelli's Experiment (page 116) is fixed in an upright position, and the height of the mercury marked from time to time, it will be found that the height of the mercury column changes slightly, thus indicating greater or less atmospheric pressure. In Torricelli's Experiment, therefore, we had a mercurial barometer in rough form.

The best form of this instrument consists of a glass tube of uniform bore about eighty centimeters long and closed at one end. After being carefully filled with pure mercury, it is inverted in a cistern of mercury. The cistern of mercury has a sliding bottom easily moved up and down by means of a set screw. At the top of the cistern there is a short ivory peg. The lower end of the ivory peg is at an exactly measured distance from the bottom of a scale. The scale is placed beside a slit near the top of a metallic tube which is firmly fastened to the cistern and surrounds and protects the glass tube.

MERCURIAL BAROMETER

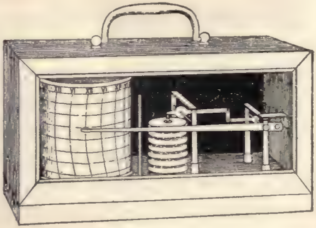
When it is desired to read the barometer, the sliding bottom of the cistern is raised or lowered

until the top of the mercury in the cistern just touches the bottom of the ivory peg. The height of the top of the mercury column is then read from the scale. In order to determine the height with great precision there is generally attached to the metallic tube a sliding vernier which moves in a slit.

ANEROID BAROMETER

The aneroid barometer consists in general of a corrugated metallic box from which the air has been partially exhausted. Within the box is a stiff spring so that the pressure of the air will not cause it to collapse. Attached to the box are levers by which any change in the volume of the box will be multiplied and indicated by a pointer arranged to move over a dial with a scale upon it.

Instruments called *barographs* are constructed in which a long lever provided with a pen point is attached to the aneroid and made to record on a cylinder revolved by clockwork. Thus a continual record is made of barometric readings.



BAROGRAPH

This is arranged so as to record the air pressure automatically for a week at a time.

Determination of Height by a Barometer. — Experiment 55. — Carry an aneroid barometer from the bottom of a high building to the top. Note the reading of the barometer at the bottom and again at the top. Why is the barometer lower at the top of the building?

As the pressure of air at any surface is due to the weight of the air above that surface, it happens that as we go up the pressure decreases, since there is a continually decreasing weight of air above. If the rate of this decrease is determined, then it is possible to determine the elevation by ascertaining the pressure.

Although the height of the barometer is continually varying with the changing air conditions, yet if these conditions remain about the same, it may roughly be estimated that the fall of $\frac{1}{16}$ of an inch in the height of the mercury column indicates a rise of about 57 feet, and that the fall of a millimeter indicates a rise of about 11 meters. These values are fairly reliable for elevations less than a thousand feet, under ordinary temperatures and pressures.

At the height of 25 miles the barometric column would probably not be more than $\frac{1}{25}$ of an inch high. Several measurements made in different ways indicate that the air is at least 100 miles in depth, probably more. Nearly three fourths of the atmosphere, however, is below the top of the highest mountain. The highest altitude ever reached by man was about 7 miles.

To study air conditions small balloons to which meteorological instruments are attached have been sent to a height of 21 miles. It is found that the minimum temperatures occur at a height of from 6 to 10 miles. Conditions affecting weather, however, seem to extend to a height of not much over 3 miles.

The atmosphere, of course, must be densest at its lowest level since the pressure due to the weight of the air is greatest there. The farther we ascend the less dense the air becomes. This is the chief reason why people from a lower altitude "get out of breath" easily when they go to a higher altitude. It is also the reason why balloons and airplanes

OBSERVATION WAR BALLOONS

can ascend only to a limited distance. Since the gas in the balloon is less dense than the lower atmosphere, it rises to a point where the density of the air just balances the average density of the balloon and its burden.

SUMMARY

The gaseous envelope of the earth is called its atmosphere. The chief gases of the atmosphere are oxygen, which is

necessary for animal life; nitrogen, which dilutes the oxygen; and carbon dioxide, which is indispensable to plant life.

Water exposed to air evaporates. Through this process, the atmosphere always contains moisture. Warm air has a greater capacity for moisture than cold air. The property that air has of taking up a large amount of moisture when heated and of depositing it when cooled is the cause of dew, fog, clouds, rain, frost, snow, and sleet. When a liquid evaporates it takes up heat from its surroundings. This principle is employed by man in ice and cold storage plants and by nature in evaporation of moisture from the surfaces of animals and plants. Care should be taken in winter to keep the air in houses supplied with sufficient moisture.

Air, like every other substance, has weight. Air expands as it is heated, and so warm air is lighter than cold air. Since the particles of air or any other gas move freely over one another, cold air will sink and force up warmer air that surrounds it. Hot air furnaces, circulation in a refrigerator, and ventilation of houses depend on this principle.

Since anything that has weight exerts pressure on the surface on which it rests, air exerts pressure at the surface of the earth, which amounts to about 15 pounds to the square inch. Lift pumps, siphons, and vacuum cleaners are among the mechanical devices that make use of air pressure.

The volume of air decreases directly as the pressure increases. When a given volume of air is compressed, it exerts corresponding outward pressure. This principle is applied in operating brakes, steam whistles, ventilating systems, heavy hammers, and force pumps.

When air or any other gas is compressed it gives out heat

and increases the temperature of its surroundings; when it expands it absorbs heat and lowers the temperature of its surroundings.

The greater the pressure on a liquid surface, the higher is the boiling point; the lower the pressure, the lower the boiling point. This principle, along with the principle that a substance absorbs heat as it changes from a liquid to a gaseous state, underlies the operation of cold storage and ice-manufacturing plants.

The barometer is an instrument for measuring atmospheric pressure. Since atmospheric pressure decreases with altitude, a barometer may be used to measure altitude.

Questions

What are the characteristics and principal uses of the three most abundant gases in the atmosphere?

What experiences have you ever had which show that hot air will hold more moisture than cold air?

How have you ever seen cooling by evaporation used?

In what ways does the moisture in the atmosphere affect bodily comfort?

How can it be shown that the air has weight and exerts pressure?

What effect has heat upon the weight and volume of the atmosphere?

Suggest several methods for properly ventilating a house.

What effect has pressure upon the weight and volume of air?

Explain the construction of three machines which make use of atmospheric pressure.

In what way do compression and expansion affect the temperature of a gas?

How are the boiling points of liquids affected by pressure? What practical uses are made of this principle?

How is ice manufactured?

How do the two kinds of barometers ordinarily used differ in construction?

CHAPTER VI

THE WATERS OF THE EARTH

Importance of Water. — Water is found to some extent everywhere on the earth's surface. It is necessary to the life of all plants and animals and makes up a large part of their weight. Man may live without food for a few weeks but cannot live more than a few days without water. The earth has been likened by some writers to a water engine, since water has played such an important part in its history.

Composition of Water. — **Experiment 56.** — (Teacher's Experiment.) — Place a small handful of zinc scraps in a strong wide-mouthed bottle. Fit the bottle with a two-holed rubber stopper having a thistle tube extending through one hole and a bent delivery tube through the other. The thistle tube should reach nearly to the bottom of the bottle. Connect the delivery tube with the shelf of a pneumatic trough by a rubber tube. Have several inverted 8-oz., wide-mouthed bottles filled with water on the shelf of the trough. (Figure 71.) Pour enough water through the thistle tube to partly cover the zinc and then pour on commercial hydrochloric acid or sulphuric acid diluted 1 to 10.

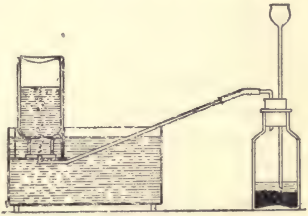


FIGURE 71

Chemical action will take place between the zinc and the acid

and hydrogen will be freed. Allow the gas to escape for several minutes, so as to rid the generating bottle of the air in it. Collect several bottles full of the hydrogen. Keep the bottles inverted. Examine the hydrogen in one of the bottles. Has it color or odor? Holding the mouth downward thrust a lighted splinter into another bottle. The splinter does not continue to burn in this gas but the gas itself burns. Place another bottle mouth up on the table and allow it to stand for several minutes. Insert a lighted splinter. Why is not the hydrogen still present?

Draw out a glass tube so that the bore will be about as large as the point of a pencil and insert it in the rubber delivery tube. Pour more acid into the bottle and after this has been working for several minutes touch a lighted match to the glass tip of the rubber delivery tube. A jet of burning hydrogen will be formed. Hold a cold, dry beaker over this burning jet. Water drops will collect in the beaker. The hydrogen is combining with the oxygen of the air and water is being formed.

Pure water is a colorless, odorless, tasteless liquid. In Experiment 15 we decomposed water by the electric current and found it to be composed of two gases, hydrogen and oxygen. In Experiment 56 we burned hydrogen, thus uniting it chemically with the oxygen of the air and forming water. Oxygen we have studied. Hydrogen is a colorless, odorless, transparent gas, the lightest of all known substances. It must be handled carefully, because if it is mixed with oxygen and the mixture is ignited, a violent explosion results.

Effects of Varying Temperatures on Water. — We have learned that water evaporates at any temperature and in so doing always absorbs heat from its surroundings. When it condenses it gives out the heat absorbed during evaporation. When water at ordinary temperatures is heated it expands until it reaches the boiling point. At this temperature, the change of water from liquid to vapor goes on most

rapidly, and the change of state increases its volume more than 1700 times. It is this stupendous pressure of rapidly generating water-vapor that is "harnessed" in the steam engine. This is one of the most marvelous manifestations of the energy of heat.

Experiment 57. — Fill a flask of about 500 cc. with water. Press into the mouth of the flask a rubber stopper through which a glass tube about 30 cm. long extends. The tube should be open at both ends and should not extend into the flask below the bottom of the cork. When the cork is pressed in, the water will be forced up into the tube for several centimeters. See that the cork is tight and that there are no bubbles of air in the flask or tube.

FIGURE 72

Now place the flask for fifteen or twenty minutes in a mixture of ice and water (Figure 72) and carefully mark with a rubber band the point at which the water in the tube comes to rest. Take the flask out of the freezing mixture and notice immediately whether the water in the tube rises or falls. Continue for five or ten minutes to notice the action of the water in the tube. The volume of the water is not the least when it is at the temperature of melting ice, 32° F., but when it is a little above this temperature.

Experiment 58. — Put a piece of ice in water. What part of its volume sinks below the surface of the water? Is it heavier or lighter than water? From Experiment 32 do you conclude that cold water is heavier or lighter than warm water?

When water at ordinary temperatures is cooled it contracts and grows denser. It continues to do this until the whole body of water reaches a temperature of about 4° C. Here a remarkable change takes place; for as water is cooled below this point it expands. This expansion goes on until the liquid turns to solid at 0° C.

At the moment water solidifies into ice, it expands with

such tremendous force that it exerts a pressure of more than 100 tons to the square foot. No wonder it bursts water pipes, splits rocks and concrete sidewalks, and heaves the foundations of buildings that have not been laid below "frost line." After ice has once formed, it again begins to contract as the temperature is lowered, but it never reaches the density of water.

It can easily be seen why any river or lake or other body of water freezes from the top down. Since water at the freezing point is less dense and therefore lighter than slightly warmer water, it remains at the surface, where it freezes. Ice is even lighter than water at the freezing point, and so it floats. As soon as ice has formed over the surface, it acts as a blanket, allowing the heat to escape only very slowly from the water underneath. Thus the ice increases in thickness so slowly that spring comes before a deep body of water can freeze to the bottom; and so fish and other forms of water life never become chilled below freezing nor suffer serious inconvenience.

Bomb Burst by Freezing Water

Ability of Water to Absorb Heat. — We have already learned that it takes more heat to raise a given mass of water one degree of temperature than to cause a like increase in temperature in an equal mass of almost any other substance. This was shown in Experiment 29. When water cools, it gives out the heat it took up when its temperature was raised. A pound of water in cooling one degree gives out about as much heat as a pound of iron in cooling nine degrees. It is for this reason that hot-water furnaces are so efficient, that hot-water bags are used to keep people warm, and that farmers sometimes in winter carry down

tubs of water to keep their cellars above the freezing point. For the same reason orange groves are often irrigated when a heavy frost threatens.

This capacity for holding heat makes bodies of water warm up slowly in the summer and cool off slowly as winter approaches. If we bear in mind that practically the entire mass of a body of water must reach a uniform temperature of 4° C. before it begins to freeze at the surface, this slowness of water to change temperature will explain why large bodies of water so seldom freeze except around the shallow edges.

Water as a Solvent. — **Experiment 59.** — Put a little salt into water in a clean beaker or drinking glass, and stir. The solid entirely disappears. Taste the water. Has the salt affected the water in any way? Pour out three fourths of the water and taste again. Is there any difference between the saltiness of the upper portion and the lower portion of the water?

FIGURE 73

Experiment 60. — (Teacher's Experiment.) — Fill a tall bottle with water colored with blue litmus. By means of a long thistle tube, slowly pour a little sulphuric acid into the bottom of the bottle. (Figure 73.) Allow the bottle to stand undisturbed and note the gradual change in color of the litmus, showing that the heavier acid is mixing, or *diffusing*, upward through the water.

Experiments 59 and 60 show that when substances are dissolved in water they tend to mix thoroughly with the water and to form a uniform solution. When we mix water, lemon juice, and sugar together to make lemonade, the solution has a uniform taste throughout. Neither the solid nor the liquid tend to separate out of the solution nor to accumulate in any one part of it. As a result of this characteristic of solutions, the water of the whole

ocean from top to bottom is practically uniform in composition.

Water is the greatest of all solvents. It dissolves to a greater or less extent almost all substances with which it comes in contact. There are, however, substances which it dissolves but slightly if at all. When it is necessary to get these substances into solution, other solvents must be used.

MONTEZUMA'S WELL

A famous water hole due to the dissolving power of water on rock-forming substances.

Gasoline, for example, dissolves grease; turpentine dissolves fresh paint, and alcohol dissolves grass stain.

Experiment 61. — Fill a small beaker with fresh water. Heat it slowly. Bubbles collect on the bottom and sides. When the water becomes cold these bubbles do not disappear immediately. If these were bubbles of water vapor, they would condense to water when the temperature was lowered. What are they? Where did they come from?

We have learned that all air has water vapor diffused through it. Experiment 61 showed that there was also

air in water. All water exposed to air has air dissolved in it. It is upon this air in solution that fishes depend for the oxygen they need. But while air may hold moisture, and water may hold air, Experiments 37 and 61 show an important point of difference between the capacity of air for water and of water for air. We learned that when air is heated it is capable of holding more water vapor. But when water is heated, it is capable of holding less air.

Experiment 62. — Stir salt, a little at a time, into a test tube of water which is no warmer than the temperature of the room. Gradually increase the salt until the water will absorb no more, and a little of the salt settles at the bottom of the test tube. Now heat the solution. What happens to the salt at the bottom of the test tube? Set the test tube containing the solution aside to cool. Does any of the salt reappear in solid form?

If we put as much of a solid substance into a liquid as the liquid will dissolve, we have a *saturated solution*. If any more of the solid is added, it will remain undissolved. As the temperature of water increases, it can hold *more solid matter* in solution. If a liquid at a certain temperature is saturated with a solid and then is reduced to a lower temperature, it will, under ordinary circumstances, deposit some of the solid. What similar thing happens in the atmosphere?

Freezing Mixtures.— **Experiment 63.** — Place some chopped ice in a beaker, and test the temperature. Add a generous amount of salt and test the temperature again. Has there been a fall of temperature?

Salt and some other substances tend to absorb water and to form a solution whenever it is possible. On a damp day salt sticks in the salt-shaker. This simply indicates that salt has absorbed moisture from the atmosphere.

It is found that when salt or any other solid is in solution in water, more heat is required to boil the solution and a lower temperature to freeze it than are required by pure water. A *saturated* salt solution freezes only at $-22°$ C. ($-7°$ F.) although pure water freezes at 0° C. The freezing point of a salt solution may, therefore, be anywhere from slightly below 0° C. to $-22°$ C., dependent upon the strength of the solution. Salt placed directly upon ice will cause the ice to melt and form a solution if the temperature is above $-22°$ C. This explains why salt may be used successfully to melt ice on porch steps, sidewalks, and car-track switches.

When ice is placed in salt water it takes from its surroundings the heat necessary to change it from the solid to the liquid state and continues to do this until the freezing point of the solution is reached. It thus happens that the temperature of such a solution may become much lower than the freezing point of water and yet the solution remain unfrozen. Most substances placed in such a solution become quickly frozen. A solution of this kind is used in freezing ice-cream. About three parts of snow or ice to one part of salt are the best proportions to use.

Substances in Suspension and in Solution in Water.— Experiment 64.— Into a glass of clear water stir a half teaspoonful of sand and fine dust. Cover the glass and set it aside. After an hour or so examine the glass and see if any of the sand and dust has settled to the bottom. If so, stir it up again. What happens?

It was found in Experiment 64 that water is able to hold solids in suspension and that the finer the solid particles the longer they stay suspended. It was also found that when the water was in motion (stirred) it held more and larger particles.

SETTLING BASINS OF THE ST. LOUIS WATER PLANT

Muddy river water is pumped into these basins and is allowed to stand until it loses its heavier sediment (Experiment 64). The combined capacity of these basins is 245,000,000 gallons.

Experiment 65. — Add some salt to the contents of the glass used in the preceding experiment. Arrange a glass funnel with a filter paper in it, as shown in Figure 74. Pour the contents of the glass into the funnel and collect the water that runs through the filter paper. Do the sand and dust run through? Put a little of the filtered water in a watch crystal or in a shallow vessel and allow it to evaporate. Did the salt in solution come through the filter paper?

FIGURE 74

Filters of all kinds are used to remove suspended materials from water; but as was shown in Experiment 65, the sub-

stances in solution cannot be removed in this way. When dirty surface water seeps down through thick enough beds of sand and porous rock, it is cleansed of its dirt; but it does not lose by this filtering process any of the substances it held in solution. On the contrary, it may have dissolved substances from the rocks through which it filtered. In this way "soft" rain water may become hard water or mineral water before it reaches the surface again in springs or wells.

A LIMESTONE CAVE

A cavern dissolved out by water. Hard water trickling in and evaporating has formed the columns.

When water has absorbed carbon dioxide it is able to dissolve limestone and it then becomes hard. When water of this kind is boiled or evaporated the carbon dioxide escapes and the lime deposits, thus rendering the water soft. Such water is called temporarily hard water. Boiler and teakettle scale are deposits from temporarily hard water. Permanently hard water cannot be softened by boiling.

Emulsions. — **Experiment 66.** — Put a few drops of kerosene or other oil into a test tube half full of water. Since the oil is lighter than the water it rises to the surface. Shake the test tube vigorously. Does the oil mix with the water? Set the test tube

aside and allow it to stand for a short time. Does the oil remain mixed with the water?

Put oil and water into another test tube and add finely shaved soap or a little soap solution. Shake the test tube vigorously and set it aside for a while. Does the oil now rise to the surface?

When the oil was shaken with the water, it divided into minute globules scattered through the water, giving the mixture a milky appearance. The oil soon separated from the water and floated on top of the water just as it did before the test tube was shaken. When soap was added and shaken with the oil and water, the globules remained in suspension and did not separate from the water when it was set aside for a while. A suspension of this kind is called an *emulsion*.

It is the power of emulsifying oil and grease that makes soap so useful as a cleansing agent. Water will not dissolve grease; but when soap solution is rubbed on oily or greasy materials, the oil or grease is converted into little droplets, each surrounded by a film of soap solution. These, with the little particles of dust and dirt which they contain, are easily removed by rinsing with water. The natural oils of the skin accumulate impurities from various sources. Since water will not dissolve this oil, soap is an essential in bathing.

If soap is used in hard water, a sticky white substance is formed which will not dissolve in water. This gummy substance is a chemical combination of soap with the mineral salts dissolved in the water. The soap combines chemically with these mineral salts until all the salts are broken up and the water is softened. Until enough soap is dissolved to soften the water, an emulsion will not form. This results in such a great waste of soap that cheaper substances such

as borax or washing soda are often used to soften water for laundry work. These substances combine chemically with the mineral salts in solution and leave the water free to form an emulsion with soap.

Pressure in Water. — **Experiment 67**.—Tie a piece of thin sheet rubber (dentist's rubber) tightly over the mouth of a small, short thistle tube. Attach tightly to the neck of the thistle tube a flexible rubber tube about two feet long. Bend a glass tube into the shape of a U, making one arm slightly longer than the other. Put colored water into the U-tube until it stands about two inches high in each arm of the tube. Fasten a meter stick in a perpendicular position and tie the U-tube to it so that the long arm lies along the scale. Attach the open end of the rubber tube to the short arm of the U-tube. When you press on the rubber sheet at the mouth of the thistle tube, the water rises in the long arm of the U-tube. You have made a simple pressure gauge. (Figure 75.)

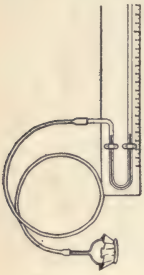


FIGURE 75

Nearly fill a battery jar with water. Slowly push the thistle tube down into the water and notice the action of the column of water in the U-tube. How does increasing depth affect pressure? Being careful to keep the center of the rubber diaphragm at the same depth, face it up, down, and sideways. Does the pressure in different directions vary at the same depth? Hold the thistle tube at equal depth in the battery jar and in a pail or tub of water. Does the greater volume of water in the pail make any difference in the pressure at the same depth?

Pressure in water varies directly as the depth, and at the same depth pressure is equal in all directions. At a given depth the volume of the water makes no difference with the pressure. The pressure would be no greater in a lake six inches below the surface than at the same depth in the battery jar. For that reason, the pressure on a water main

issuing from the bottom of a standpipe would be just as great as from a reservoir of great area, provided the depth of water in each is the same. It follows, therefore, that the bottom of a standpipe supporting a fifty-foot column of water would have to be just as strong as the bottom of a dam holding back the waters of a lake fifty feet deep. Of course in a heavier liquid than water, pressure would increase more rapidly with the depth; and in a lighter liquid, less rapidly.

Another important property of water and of all other liquids is that they transmit pressure equally in all directions. If a bottle be completely filled with water and pressure be suddenly applied to the stopper, the transmitted pressure may break the sides of the bottle. If the area of the face of the cork that pressed upon the surface of the water in the bottle were one square inch and the pressure applied to the cork were twenty-five pounds, then the twenty-five pounds of pressure on the square inch of water surface would be conveyed to every square inch of the inner surface of the bottle.

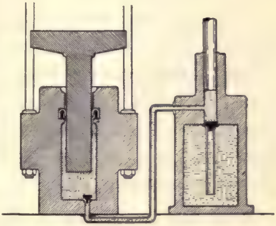


FIGURE 76. — HYDRAULIC PRESS

This property liquids have of transmitting pressure equally in all directions has many practical applications. One of the most common is the hydraulic press (Figure 76). In this machine a relatively small amount of pressure on the small piston achieves tremendous results at the large piston. Suppose, for example, the area of the face of the

small piston is one square inch and the area of the face of the large piston is 100 square inches. If a pressure of 25 pounds were exerted downward on the small piston, an equal pressure would be exerted upward on every square inch of the face of the large piston. Thus 25 pounds pressure on the small piston would cause an upward pressure of 2500 pounds on the large piston.

In the operation of this press, the large piston would rise only one hundredth as far as the small piston descended. If the small piston descended a foot, the large piston would rise one hundredth of a foot. In other words, the pressure on either piston times the distance it travels equals the pressure on the other piston multiplied by the distance it travels.

The enormous force that can be exerted by the hydraulic press is used in baling cotton and paper, in punching holes through steel plates, in extracting oil from seeds, in lifting huge machines, and in many other devices where immense pressure is needed.

Buoyancy of Water. — **Experiment 68.** — Prepare a block of wood having dimensions of 6×4×4 cm. Bore a hole in one end of the block and fill it with sufficient lead so that it will readily sink in water. Tightly close the hole containing the lead and dip the block in melted paraffin to make it entirely waterproof. Carefully measure the block and compute its volume in cubic centimeters.

Drive a small tack into the center of one of the smaller faces of the block. Attach a thread to the tack and lower the block into a cylinder graduated to cubic centimeters. Pour into the cylinder more than enough water to cover the block. Read on the cylinder scale the combined volume of the block and the water. Pull the block out of the water. Read on the scale the volume of the water left in the cylinder. Does the difference between the two readings equal the computed volume of the block?

From this experiment we learn that a body submerged in water displaces a volume of water equal to its own volume. A cubic block measuring exactly 96 cubic centimeters would displace 96 cubic centimeters of water.

Experiment 69. — Attach the block prepared for the previous experiment to a spring balance with a scale reading in grams, and weigh it. Lower the block suspended from the scale by a thread into a vessel of water until it is entirely submerged. Does the block appear to weigh as much now as when out of water?

Compare the difference between the weight of the block in air and its apparent weight in water, with the weight of the water which the block displaced in the preceding experiment. One cubic centimeter of water weighs a gram.

From this experiment we learn that a body appears to lose weight when it is submerged in water and the amount of weight it loses is exactly equal to the weight of the volume of water it displaces. If a cubic centimeter of lead is weighed in water it will be found to weigh one gram less than in air. In other words the lead is pushed upward, or buoyed up, by a force exactly equal to the weight of a like volume of water.

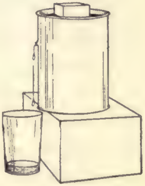


FIGURE 77

Experiment 70. — If convenient use an "overflow can." If not punch a hole near the top of a large tin can. (Drive the punch from the inside so that the flange will be on the outside.) Smear a little vaseline around the inside and the outside of the hole so that water will not cling to the tin. Place the can on a box on the table and fill with water until the water begins to run out of the hole. (Figure 77.) Accurately weigh a block similar to the block used in Experiment 68, but containing no lead. Weigh also a dry beaker. Place the beaker so that it will catch all the water overflowing from the hole in the tin can. Place the block in the can. As soon as water has ceased to run

into the beaker, weigh the beaker with the water in it. Subtract the weight of the dry beaker from the weight of the beaker containing water, and you will have the weight of the water displaced by the block of wood. Compare this weight with the weight of the block.

Mark on the block the depth to which it sinks. About how much of the block was submerged?

A body floating in water displaces its own weight of water. Thus if a body is half as dense as water, it will sink half

U. S. official

AN AMERICAN SUBMARINE

its volume; if one third as dense, it will sink one third its volume. Representing the density of water by 1, what decimal fraction would represent the approximate density of the wood in the experiment? The density of any substance as compared with the density of water is known as the *specific density* of the substance. A solid piece of iron is much denser than water and when submerged displaces much less than its own weight of water. It therefore sinks. But an iron dish will float because its volume is so great that it displaces a weight of water equal to its own weight. If a hole is made in the dish and water is allowed to enter the

hollow space, the dish begins to sink. The depth to which it sinks may be regulated by the amount of water admitted.

Submarines are boats so constructed as to be water-tight even when submerged. Special compartments are provided to which water can be admitted and from which it can be driven out. When the commander of a submarine wishes to submerge his vessel, he gives the order to admit sufficient water to the compartments to make the submarine heavier

U. S. official

A SUBMARINE SUBMERGING

than an equal volume of water. It therefore sinks. In order to make the submarine rise, the operators must force water out of the tanks until the submarine displaces a weight of water greater than its own weight. It will then rise and float partly submerged. If just enough water is admitted to the tanks to make the weight of the submarine equal to the weight of the water displaced, the submarine can be made to float at varying depths.

Animal Life in Water. — From previous experiments we

have learned some of the chief physical properties of water, and so perhaps we can understand the different effects that water has had upon the development and activities of living things. Some water animals move about easily to get their food, but others have it brought to them in solution and so obtain it without muscular effort. The air that they breathe is in solution and they cannot as easily obtain a large quantity of it as can the land animals. Since the energy of all animals depends upon the amount of oxygen they use in their bodies, the water animals are generally less energetic than the land animals. Since they also have such an easy time in moving or floating about to get the things they need they have not developed as high organisms as the land animals.

CORALS

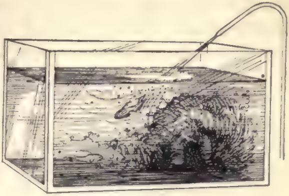
Fixed animals whose food is brought to them in solution by the ocean currents.

Ocean Waters. — The oceans which cover almost three fourths of the earth's surface are the inexhaustible reservoirs from which come, directly or indirectly, the waters of rivers and lakes, of wells and springs, and the moisture of atmosphere and soil.

Experiment 71. — If ocean water can be obtained, boil down about a pint of it in an open dish. Taste the residue. What is the principal constituent of this residue?

There is probably no water on the surface of the earth which is absolutely pure. All ordinary water has come in contact with some substances which it could dissolve.

When the river waters run into the sea, they carry with them whatever they have dissolved from the land. When the water of the sea evaporates and is borne away, to fall upon the land again, the dissolved material is left behind in the ocean.



"AIRING" AN AQUARIUM

Fishes may die in the still water of an aquarium for lack of fresh air. The small stream from the tube stirs up the tank-water and causes it to absorb air.

Thus the sea has for all time been receiving soluble contributions from the land. It is easy to prove that it contains salt, for we can taste it. It must contain lime, since coral and shell animals of the sea depend upon it for the hard parts of their bodies. There must be organic food material in it, or else fixed animals like corals could not get their food. It contains air, for without air fishes could not breathe. These are the principal substances which we need consider in the study of ocean water, but the chemist can find many other substances dissolved in it. There is so much dissolved material of different kinds in it that the density of the solution is sufficient to keep ocean water from freezing until it reaches 28° F., instead of 32° F., the temperature at which fresh water freezes.

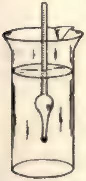


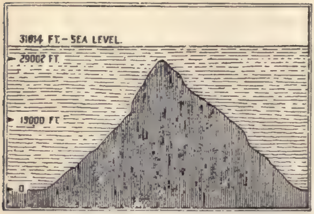
FIGURE 78

Experiment 72. — Place in a deep dish of fresh water a density hydrometer (Figure 78), or stick loaded with lead at one end so that it will float upright. Mark with a rubber band the depth to which the hydrometer sinks in the water. Now place the hydrometer in sea

water and mark the depth to which it sinks. If sea water cannot be obtained, dissolve in a pint of fresh water about 15 g., or half an ounce, of salt. This will give the water about the same amount of dissolved solid material as sea water has. About how much more of its length does the hydrometer sink in fresh water than in sea water? Will a piece of ice project more out of salt water than it would out of fresh water?

On account of the materials dissolved, sea water weighs more than fresh water, or has a greater specific density. Floating bodies therefore have less of their volumes submerged in sea water than in fresh water. A cubic foot of sea water weighs over 64.25 pounds, whereas a cubic foot of fresh water weighs only about 62.5 pounds. The specific density of sea water is about 1.03.

Ocean Depths. — The greatest depth thus far found in the ocean is over six miles. This was found in the Pacific Ocean near the Philippine Islands. The greatest depth in the Atlantic Ocean thus far discovered is a little over five miles at a point north of Porto Rico. The average depth of the sea is probably about two and one half miles.



Mount Everest

As it would appear if placed in the deepest part of the sea.

Although the pressure at the bottom of the ocean must be tremendous, yet so incompressible is water that a cubic foot of it weighs but little more at the bottom of the sea than it does at the top. Thus a body which readily sinks will in time reach the bottom, no matter what

the depth may be. At a depth of two miles the pressure is over 300 times as much as at the surface of the water; and here, as we have already found, it is about 15 pounds to the square inch.

If a bag of air which had a volume of 300 cubic inches at the surface were sunk in the ocean to a depth of two miles, it would have a volume of less than a cubic inch, and the pressure upon it would be several tons. It thus happens that deep sea fishes when brought to the surface have the air in their swimming bladders so expanded that the bladders are often blown out of their mouths.

CRINOID

A sea animal once abundant but now found only in deep oceans.

Conditions of the Ocean Floor. — The ocean floor is a vast, monotonous, nearly level expanse whose dreary, slimy, and almost lifeless surface is enveloped in never-ending night and is pressed upon by a vast weight of almost stagnant frigid water. Here and there volcanoes rise upon it with gradually sloping, featureless cones, and sometimes a broad, wavelike swell reaches within a mile or so of the surface. Such a swell extends along the center of the Atlantic Ocean through Ascension Island and the Azores.

There are no hills and vales, no mountain ranges having sharp peaks and deep valleys. Gradually rising ridges and volcanoes, sometimes topped with coral islands, alone vary the monotony. It is the nether world of gloom and unaltering sameness. Here the derelicts of ages past, after their fierce buffeting with wind and wave, have found a quiet, changeless haven where they may lie undisturbed until absorbed into the substance of the all-enfolding water.

The Carpet of the Ocean Floor. — Near the shore, the floor of the ocean is covered with sand and mud derived from the waste of the land. In the deeper sea the covering is a fine-textured material of animal origin called *ooze*. It is composed of the shells of minute animals that live near the surface.

At a depth of about 3000 fathoms (18,000 feet) these shells disappear and a reddish clay appears. This clay is believed to be due to meteoric and volcanic dust and to the insoluble parts that remain after the calcareous (lime-like) material of the minute shells has been dissolved in sinking through the deep water. No layers of this kind have ever been found on the land, and this is one of the reasons for believing that the depths of the sea have never been elevated into dry land, but that what is now deep ocean has throughout all time been deep ocean.

Temperature of Ocean Waters. — Sea water continues to contract as it cools until it is of about the freezing temperature of fresh water. Hence cold water near the poles gradually sinks and creeps under the warmer water of lower latitudes, maintaining a temperature of 32° to 35° on the bottom, even at the equator. This steady creep of cooled surface water along the bottom supplies the animals

of the deep ocean floor with the air which they must have. Without it the water at great depths would have its air exhausted and all life would be destroyed.

At the surface of the ocean the temperature of the water varies in a general way with the latitude; it is over 80° at the tropics and about the freezing point at the poles. Near the poles and near the equator there is very little variation in the temperature of the surface water during the year, but in the intermediate latitudes the annual variation is considerable. Below the surface the effect of solar heat rapidly diminishes and at a depth of 300 ft. it is probable that the annual variation in temperature is nowhere more than 2° F. Below 600 ft. there is probably no annual change in temperature.

Waves. — **Experiment 73.** — Take a long, flexible rubber band or tube and having fastened one end, stretch it somewhat. Now strike down on it near one end with a small stick. A wavelike motion will be seen to travel from end to end of the band. It is evident that the particles of rubber do not enter into the lateral movement, but that they simply move up and down, whereas the wave movement proceeds along the band. A piece of paper folded and placed lightly upon the band will move up and down but not along the band. Thus, wave motion does not necessitate lateral movement of the particles taking part in the wave.

When the wind blows over water, it throws the surface into motion and produces *waves*. The highest part of the wave is called the *crest* and the lowest part the *trough*. Trough and crest move along rapidly over the surface of the water. The particles of the water themselves, however, move somewhat like those in the rubber band. That the water itself does not move with the wave can be seen when a floating bottle is observed. It moves up and down

but does not move forward. If the water moved along with the waves, it would be next to impossible to propel a boat against the direction of the wave movement.

That it is possible to generate wave movement without the particles themselves moving along with the wave is seen when a field of grain is bending before a gentle wind. The troughs and crests move one after the other across the

OCEAN WAVES

field but the heads of grain simply vibrate back and forth. The crest of a water wave, however, is often blown forward by the wind and thus a drift in the direction of the wind is established at the surface.

When great waves are raised by the wind at sea, there is danger that the mighty crests may be blown forward and engulf a ship. To calm the waves ships sometimes pour "oil on the troubled waters." The oil spreads out in a thin film over the water and forms a "slick" which

prevents the wind from getting sufficient hold upon the water to topple over the crests, and thus the danger of being swamped is averted. It has been found that oil will spread out even in the direction of the severest wind.

Although sometimes waves are spoken of as "mountain high," it rarely happens that the height from trough to crest is over 50 ft. The movement of the waves stirs up the water and enables it more freely to absorb the air which is so necessary for the existence of water animals.

FINGAL'S CAVE

Waves as Destroyers and Builders. — Wherever the waves strike on an unprotected shore, they wear it away. The rapidity of the cutting and the forms carved depend upon the strength of the waves and the kind of shore. Wherever there is a point of weakness along the shore, there the waves cut back more rapidly. The harder parts stand out sharply

as points and promontories. In some cases the waves cut back so rapidly on lofty coasts that high cliffs are formed.

If the material of the coast does not readily break off when undercut by the waves, a sea cave may be formed. Such is the well-known Fingal's Cave on an island off the coast of Scotland where the structure of one of the igneous rock layers allows the waves to quarry it comparatively easily. If a coast stays at the same elevation long enough, or if its material is easily eroded, large areas of what was formerly dry land may be cut away and brought under the sea.

A LAKE BEACH FORMED BY A STREAM AND WAVE ACTION

A year after this picture was taken a landslide caused a wave which swept away the entire beach and village.

In 1399 Henry of Lancaster, afterward Henry IV of England, returned from his exile and landed at Ravenspur, an important town in Yorkshire, to begin his fight for the crown. A person disembarking at the same place to-day would be so far from shore that he would need to be a sturdy swimmer to reach the beach. The entire area of the ancient town has been cut away by the waves and now lies under the sea. This

is an example of what has occurred in many seacoast regions.

Unless the material pillaged from the land by the waves falls into too deep water, it is buffeted about by them and broken and worn into small pieces. These are then borne along by the shore currents until they find lodgment in some protected place where they can accumulate. When sufficient material has been accumulated, the storm waves

A SAND SPIT, FORMED BY WAVES AND CURRENTS

and the wind sweep some of it above sea level and fringe the water's edge with a border of water-worn sand and pebbles. These accumulations of shore drift are called *beaches*.

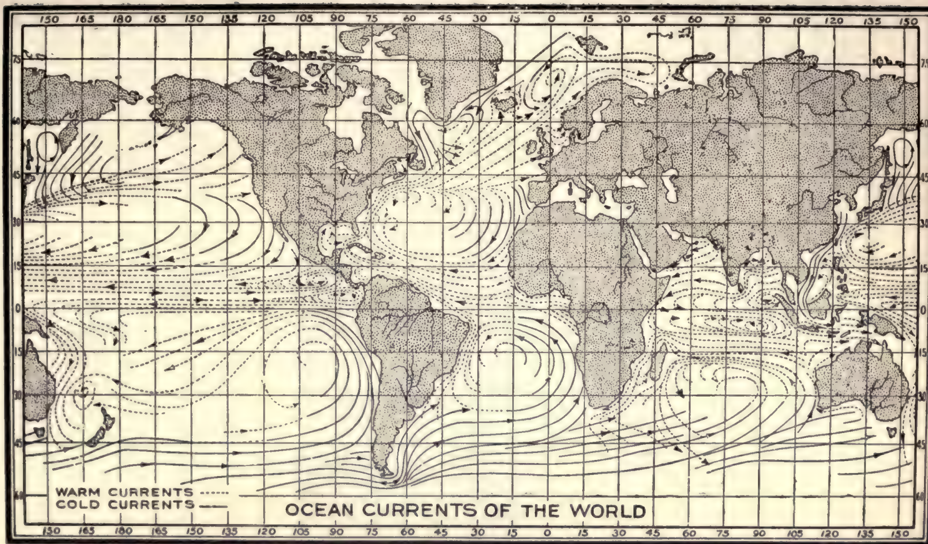
Currents moving loose material with them sometimes form it into bars which tie islands to the mainland or extend into the sea free ends, forming what are called *spits*. A famous example of a land-tied island is that of the great English fortress at Gibraltar. Although now a promontory, it

was once an island detached from the coast of Spain. Shifting sand bars, especially if covered with water, are exceedingly dangerous to vessels, and coasts where these are abundant need especial protection by lighthouses and life-saving stations. The greatest Mediterranean port of France during the thirteenth century, Aigues-Mortes, has been closed in by sand bars so that there is no longer access to the sea and only the relics of the former great city now exist. Thus have the moving sea-sands overthrown the plans of men.

Ocean Currents. — The ocean is a region of never-ceasing motion. At considerable depths its motion is very slow, but near the surface, where the prevailing winds can affect it, the movement is considerable. Circulating around each ocean there is a continuous drift of surface water extending to a depth of from 300 to 600 feet and varying in rate from a few miles up to fifty or more miles a day. In fact these rotating currents are the chief natural basis for the division of the oceanic area into six oceans, as our geographies generally divide them.

These currents circulate in the northern hemisphere in the direction in which the hands of a watch move and in the southern hemisphere in the opposite direction. In the centers of these rotating areas the water is nearly motionless and here are often found great masses of floating seaweed filled with a great variety of small animals. These accumulations of seaweed are called *sargasso seas*.

The temperature of winds blowing from the sea is modified by these currents and greatly affects the habitability of the earth for man. The editor of the National Geographic Magazine makes the striking statement that "the Gulf Stream carries enough heat toward Europe every twenty-



OCEAN CURRENTS OF THE WORLD

four hours to melt a mass of iron as large as Mount Washington. Hammerfest at 71° north is a flourishing seaport, but there are no important settlements above 50° on the western side of the Atlantic. Alaska, the prevailing winds of which are warmed by blowing over the warm ocean, is a region which promises much for human habitation, while the region on the opposite side of the Pacific must remain almost destitute of human inhabitants. It should be noted that the effect of the warm ocean waters would be slight, except along the coast, were it not for the air movements.

HIGH TIDE IN NOVA SCOTIA

Tides. — Probably the first thing that impresses us on visiting the seashore is the regular rising and falling of the water each day. These movements of the water are called *tides*. If we observe the tides for a few days, we find that there are two high and two low tides each day. As the tidal current comes in from the open ocean and the water rises, it is called *flood tide,* and as it runs out or falls, *ebb tide*. When the tides change from flood to ebb or ebb to flood, there is a brief period of "slack water."

If we observe closely, we shall see that the corresponding tides are nearly an hour later each day than they were

the day before, and that the time required for the completion of two high and two low tides is nearly 25 hours. Continued observation will show, as Julius Cæsar stated many centuries ago, that there is apparently a relation between the phases of the moon and the height of the tides. The greatest rise and fall of the water will be found to occur about the time of full and new moon.

It has been found that the position of the sun, as well as that of the moon, affects the height of the tide. If the earth, moon, and sun lie in nearly the same line, the tidal range is greatest. This is called *spring tide.* When the sun and moon act at right angles upon the earth, the tidal range is least and this is called *neap tide.* The tidal undulations have been proved by astronomers to be due to the rotation of the earth and the gravitational attraction of the sun and moon upon its water envelope. The moon is much more effective because it is nearer.

Low Tide at the Same Place

The tidal current as it sweeps between islands often forms eddies and whirlpools which make navigation very dangerous. An example of this is found at Hell Gate, New York, and at the famous Maelstrom off the coast of Norway. On the other hand, in flat countries where the

rivers are shallow, ports which could not otherwise be reached are made accessible to ships of considerable burden at the time of high tide. At these places the time of leaving or making port changes each day with the time of high tide. A striking example of this is the port of Antwerp.

The tidal currents are also continually changing the water in bays and harbors and thus keeping them from becoming stagnant and foul. They also bring food to many forms of inshore life which have but little or no power of movement, such as clams and other shellfish. The ebb of the tide exposes some of these and gives man a chance to acquire them readily for food.

Man and the Ocean. — At first thought it would seem better for the life of the world if the proportion of land and water were reversed. Yet when we consider that almost barren wastes constitute many continental interiors and that plenty of rainfall is necessary to make land habitable, the utility of the great water surfaces becomes apparent. From the evaporation of the ocean surface comes nearly all the water which supplies man, land animals, and plants.

It is not only true that all streams eventually run to the sea but it is also true that all their water comes from the sea. Other things being equal, the smaller the surface for evaporation the less the water supplied to the land. Besides supplying the land with water, the ocean has a great effect on its climate.

The animals of the sea also furnish food for thousands. The value of the world's fishery products is nearly one half billion dollars a year. A large part of the earth's population is now, and always has been, located not far from the shore of the ocean.

In early times before the advent of railways almost all commerce was carried on over the sea. Even now this is the cheaper way of transportation. Modern methods of conveyance have enabled man to live with comfort at a considerable distance from the ocean, but the dry interiors of continents still remain sparsely inhabited. All commercial nations must have an outlet to the sea and to obtain it much blood and treasure have often been spent.

SUMMARY

The earth has been called a water engine since water has played such an important part in its history. Pure water is a colorless, odorless, tasteless liquid, composed of two gases, hydrogen and oxygen. Water may evaporate at any temperature, but evaporation goes on most rapidly at the boiling point. As water above 4° C. increases in temperature, it increases in volume. When water changes from a liquid to a gas, its volume increases more than 1700 times. Water in cooling grows denser until it reaches about 4° C. It then begins to expand and continues to do so until it freezes at 0° C. When it freezes it exerts a pressure of more than 100 tons to the square foot. The entire mass of a body of water must reach a temperature of about 4° C. before it begins to freeze at the surface.

Water is the greatest of all solvents but it does not dissolve every substance. The higher the temperature of water, the less air but the more solid matter it will hold in solution. A mixture of ice, salt and water is called a freezing mixture because the solution attains a temperature lower than that of melting ice. All solutions freeze at a lower temperature than that at which pure water freezes. Water may also hold substances in suspension. The greater the movement of water

the more it will hold suspended in it. Oils and fats, which do not dissolve in water, may be suspended in water by emulsion.

Water, like air, *exerts pressure*, the amount of which depends on the depth of the water. The pressure at any given depth is equal in all directions. Water also *transmits pressure* equally in all directions.

A submerged body displaces a volume of water equal to its own volume, and loses weight exactly equal to the weight of the water displaced. If a body weighs less than an equal volume of water it floats; if more, it sinks.

Animals that live in water obtain the oxygen they need from air in solution. Since an animal's energy depends largely on the amount of oxygen it consumes, water animals are generally less energetic than land animals.

The oceans are the earth's water reservoirs. The seas have for all time been receiving soluble contributions from the land. When water evaporates, the dissolved substances are left behind. Thus sea water is denser than fresh water and freezes at a lower temperature. The greatest depth thus far found in the ocean is more than six miles. At the depth of two miles, the pressure is more than 300 times as much as at the surface. The ocean floor is an almost level expanse with only occasional volcanoes or gradually sloping swells. Near the shore mud and sand washed from the land cover the ocean floor. In deeper water the ocean floor is covered with ooze, and below 18,000 feet with a peculiar reddish clay, not found elsewhere. At the surface, the temperature of ocean waters varies in general with the latitude. Below the surface, the effect of solar heat diminishes rapidly. Below 600 feet there is probably no annual change in temperature, and at the bottom a steady temperature of 32° to 35° F. is maintained.

Waves are caused by up and down, not by lateral, movement of the water affected. The power of waves and tides to cause erosion results in their acting as destroyers of unprotected shores. The solid matter eroded and carried in suspension is often deposited at quieter places along shore. Thus waves and tides may also act as builders. Ocean currents are drifts of surface water, some of which, due to the winds blowing over them, have very important effects on the climate of adjoining lands. Tides are movements of the water envelope of the earth caused by the rotation of the earth and the gravitational attraction of the sun and the moon — chiefly the latter. Oceans furnish the water which supports land life, food for thousands of people, and pathways of commerce for all nations.

Questions

What is the composition and what are the most striking characteristics of water?

Why does a freezing mixture freeze substances placed in it and yet itself remain unfrozen?

What is the difference between an emulsion and a solution?

Why is soap used in cleaning?

Explain the principle of the hydraulic press.

How could a piece of lead be made to float in water? Why?

Mention some ways in which ocean water differs from distilled water.

Waves and currents are both primarily due to winds. How do they differ in action and effect?

What are tides and their cause?

Of what advantage is the ocean to man?

CHAPTER VII

THE WORK OF RUNNING WATER

The Sphere of Activity of Rain. — When rain falls upon the ground, it may do one of three things. It may evaporate immediately from the surface and return to the air; or it may run rapidly off the surface and quickly join the streams and rivers which bear it to its final goal, the sea; or it may sink into the ground. In this last case part of it returns gradually through capillary action to the surface, where it is again evaporated; part finds its way into springs; and part sinks deep into the soil and rock.

Experiment 74. — (Teacher's Experiment.) — Attach one end of a rubber tube to a faucet in a sink. In the other end of the rubber tube insert a glass tube drawn out to a point, so that when the faucet is opened the water will issue from the glass tube in a fine stream. Arrange to play this stream into the concave surface of a spoon so that the reflected and widened spray will fall over about a square foot of surface. (Figure 79.)

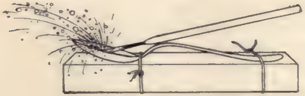


FIGURE 79

Take a long, shallow, flat-bottomed pan and punch a row of holes in one end of it, a little above the bottom. At the other end, and covering about two thirds of the bottom of the dish, arrange several thin, irregular layers of fine sand, salt, fine clay, coal dust, or other fine materials. Tilt the pan slightly so that the fine materials

may occupy the upper two thirds of a gentle slope and the bare surface of the pan with the drainage holes, the lower one third.

Allow the spray from the spoon to play over the layers in the dish for some time. Tiny rivulets will grow in the layered surface, gradually deepening and extending their valleys, and more and more thoroughly dissecting the surface. Deltas will be formed in the still water in the lower part of the pan, and many of the erosion phenomena of a stratified, slightly elevated region will appear. (Figure 80.)

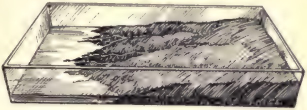


FIGURE 80

Run-off. — The rain that falls upon the land and neither evaporates nor sinks into the surface runs off as fast as it can toward the sea. It is joined sooner or later by the water from the springs and by the rest of the underground drainage. Sometimes the journey is long and there are many stops and delays in lakes and pools; sometimes the course is quite direct and quickly traveled. The run-off most profoundly affects the earth's surface. Gullies and valleys are cut, depressions are filled; in fact, running water is the chief tool which has carved the features of the earth. It has had a long time to act and it has kept unremittingly busy, so that the results of its action appear now in our varied landscape.

Lakes. — The water which runs off the surface first fills the depressions. As soon as these are filled, it runs over the lowest part of their rims and starts again on its course to the greatest of all depressions, the sea. If depressions of considerable size become filled with water, we call them *lakes*.

The streams that flow into lakes are continually bringing down the sand and mud they have gathered in their course, and are thus filling up the lakes.

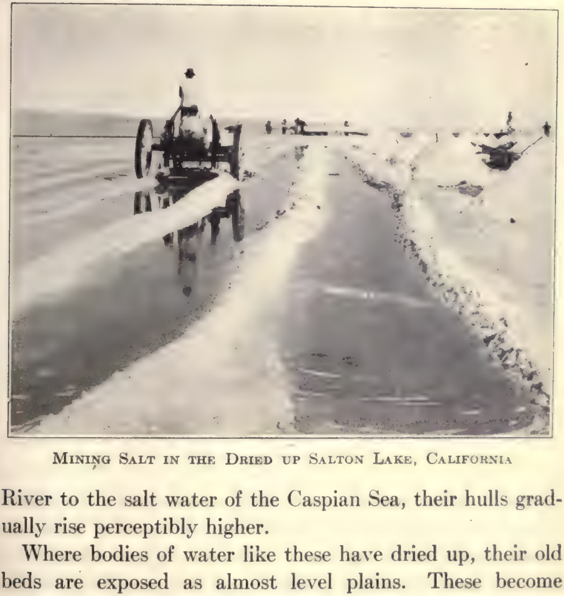
The outlet to a lake tends to wear away its bed, but it does this slowly, as it has little sediment with which to scour. Thus lakes are being constantly filled and drained, and so are comparatively short-lived features of the earth.

Lakes are very important features to man. They filter river water so that rivers emerging from lakes are clear. Where the Rhone enters Lake Geneva, it is turbid and full of silt, but when it emerges, it is clear and without sediment. Lakes also act as reservoirs for the water that pours into them at the time of freshets. Rivers emerging from lakes of considerable size vary little in the height of their water at different seasons of the year. They are without floods. The St. Lawrence illustrates this. On the other hand the Ohio, with its frequent and terribly destructive floods, shows the effect of unrestrained run-off.

In some regions the rainfall is so small that the depressions never fill up sufficiently to overflow their rims. The water is evaporated from the surface as fast as it runs into the lake. Thus all the salt and other soluble substances which have been extracted from the land and brought into the lake by the rivers remain there, since only pure water is evaporated. In this way lakes without outlet become salt. Great Salt Lake in Utah is an example of this. Some salt lakes, like the Caspian Sea, were probably once a part of the ocean, so that they have always been salt.

As time goes on, more salt is brought to these lakes without outlets, and they become more and more salty. Great Salt Lake has something like 14 or 15 per cent of solid

material in its water, the Caspian Sea about 13 per cent, and the Dead Sea about 25 per cent. An effort to swim in these waters gives one an exceedingly queer sensation. The buoyancy is so great that a large part of the body is out of water, and one finds oneself bobbing around like a cork. When boats pass from the fresh water of the Volga



MINING SALT IN THE DRIED UP SALTON LAKE, CALIFORNIA

River to the salt water of the Caspian Sea, their hulls gradually rise perceptibly higher.

Where bodies of water like these have dried up, their old beds are exposed as almost level plains. These become exceedingly fertile under irrigation as soon as the salts are dissolved and drained out of the soil. Fine examples of this are the fruitful plains near Salt Lake City and in Imperial Valley, California.

Depressions that are very shallow and are largely filled with vegetable growths are called *swamps*.

The Power of Running Water. — Running water has the power of carrying solid materials. If it is moving slowly, this power is not great; if moving swiftly and in great volume, it is tremendous. The carrying power of a stream

LAKE DRUMMOND

A lake in Dismal Swamp, Virginia, which is being filled by vegetable growth.

increases very rapidly if its velocity is increased. A stream having its velocity doubled will carry several times as much material as before. Thus it happens that water running over a surface sweeps loose material with it, the amount varying with the rapidity and volume of the flowing water.

As this loose material sweeps over solid surfaces, it cuts them down. Thus flowing water is continually wearing

down and sweeping away the surface over which it moves. This sort of work is called *water erosion.*

When running water is concentrated into a stream, the work of erosion is also concentrated and the wearing down of the stream bed becomes comparatively rapid. This cutting down goes on irregularly, being greatest at time of flood and least when the flow is slight.

GULLIES BEING CUT BY RUNNING WATER

Divides. — If we carefully observe the drainage of a region, we find that the areas from which different streams gather their water are usually so distinctly separated from one another that a line could be drawn so that wherever water falls the rivulets on one side would flow into one stream and on the other side into another. Such a line of the highest land between the drainage areas of neighboring streams is called a *divide.* The line may be very distinctly marked, as on mountain ridges, or it may be difficult to determine, as in a flat country, but if the drainage is well established, it will be apparent.

If the drainage is not well established, areas may be found which at one time drain in one direction and at another time in another.

Thousands of years ago, during the Glacial Period, Lake Michigan drained into the Mississippi system. In recent geological times it has drained into the St. Lawrence system. Chicago, by dredging a drainage canal along an

DIVIDES BETWEEN STREAMS

The ridge in the center of the picture separates two streams flowing in opposite directions.

ancient outlet, has restored part of the drainage of the lake to the Mississippi system.

Divides are irregular in their height, so that roads and railways in passing from one drainage basin to another usually seek out the lowest part of the divide. In mountain regions these low places are called *passes*.

River Development. — The rain which falls upon a flat country runs off very slowly, a large part of it soaking

into the ground. Pools and lakes are formed in the inclosed basins, and sluggish streams with irregular little crooks, which show that the streams have hardly decided where they want to go, wander in the slight depressions

NIAGARA FALLS

down the gentle slopes and unite with other streams here and there until a river of ever increasing size is formed.

In some places the streams flow through lakes where they deposit their sediment, thus filling the lake basins. Here and there they pass over hard layers of rock which

hold them up in falls and rapids. These they at once begin to smooth down. Rivers of this kind may well be called *young*, as their life work is just beginning. The Red River of the North, with its shallow, narrow valley and tortuous course, and the Niagara River, with its lakes and falls, are examples of young rivers.

STREAM WORKING BACK INTO AN UNDISSECTED AREA

Where the slope of the newly exposed surface is considerable, the streams flow much more rapidly and develop their courses more quickly. The small irregularities are sooner straightened and the trough deepened, thus forming side slopes down which run little rivulets which in time form side streams. The heads of these, like the heads of the larger streams, are constantly working back into the undissected area. Gradually the side streams develop side

streams of their own, and almost the whole surface is covered with a network of streams.

As the work of erosion goes on and the streams deepen their valleys, only a few imperfectly drained remnants of the former flat surface are left here and there. These lie

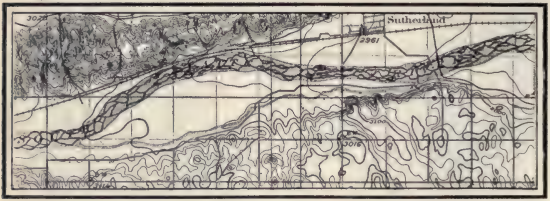
YELLOWSTONE RIVER

A river flowing in a deep narrow trough.

between the larger streams in places which the side streams have not as yet been able to reach. Almost the entire surface is so intricately carved into drainage lines that wherever water falls it immediately finds a downward sloping surface. The main stream by this time has probably smoothed out most of its falls and rapids and has developed long, smooth stretches.

Here it is no longer cutting down its trough, but has only sufficient slope to enable it to bear along its load of waste. It here deposits upon its valley floor about as much as it takes away. In this part of its course a river is said to be *graded*. The longer a river flows undisturbed by any deformation of its valley, the fewer falls and rapids it will leave and the longer will be its graded stretches. The Missouri River near Marshall, Missouri, is an excellent example of a graded river.

Sometimes a stream becomes so overloaded with detritus, which it has acquired in a steeper part of its extent, or



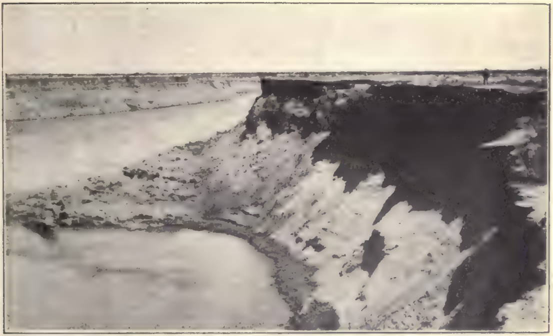
PLATTE RIVER

which has been brought to it by tributaries, that it is continually being forced to deposit some of its load. Thus it silts up its course and flows in a network of interlacing shallow channels. The Platte as it crosses the plains of Nebraska is an example of such an overloaded river.

When a stream swings around a curve, the swiftest part of the current is on the outside of the curve and the slowest on the inside. A river that is carrying about all the load that it can, on passing around a curve, is able in its outer part to carry more than before and cuts into the bank, while on its inner part it flows less rapidly and is able to

carry less, thus being forced to drop some of its load. As a river flows along its graded stretches, eroding in some places and filling in others, it broadens its valley floor, leaving at the border of its channel a low plain which in time of flood may be covered with water.

These plains are very fertile and are usually called "bottom lands" by the farmers. They are often unhealthy



River Erosion

Cutting down the outer side of the curve and depositing on the inner.

because of floods and poor drainage. Where the water in the river rises rapidly and to a considerable height, it is dangerous to inhabit these plains. But sometimes these plains are so fertile that they are densely populated, as the plain of the Ganges. Such a river-made plain is called *a flood plain.*

If a river once begins to swing on its valley floor, it continues to do so, since whenever it strikes the bank, it is deflected toward the other side, and is made to move in the direction of the opposite bank as well as downstream.

The windings that it thus assumes on a flat valley floor are roughly S-shaped and are called *meanders*, from the name of a river in Asia Minor which was, in very ancient time, noted for having such swinging curves. The size of these curves will be proportional to the size of the river.

Great rivers like the Mississippi have a swing of several miles, while a small stream may have a swing of only a

Bottom Lands

few feet or rods. These meanders are continually changing their shape, owing to the cutting and filling.

The meanders sometimes become so tortuous that the downstream side of one curve approaches the upstream side of another and even cuts into it, thus causing the river to desert its curved path and straighten itself at this point. The old deserted winding looks something like an oxbow, and when filled with water, is called an *oxbow lake.*

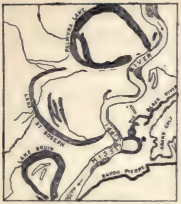
Sometimes the meanders are artificially straightened, as has been done in the lower Rhine valley, and much arable land reclaimed.

In time of flood, when a river spreads over its flood plain, the velocity of the water is checked outside the channel and some of the sediment it carries is deposited. The most

Stream Meandering on its Flood Plain

sudden check in velocity occurs where it leaves the channel, so more material will be deposited here than elsewhere on the flood plain. The banks of the channel will thus be built up more rapidly, and the flood plain near the river will slope away from the channel instead of toward it.

This is well shown in the lower Mississippi, where the river is found to be flowing on a natural embankment, the side streams running away from the river instead of into



OXBOW LAKES
A stretch of the Mississippi and some of its abandoned meanders.

it. In some places the embankment is fifteen or twenty feet above the rest of the flood plain. These natural *levees,* as they are called, often force the tributary streams to flow for long distances upon the flood plain before they can enter the main river. The Yazoo River is forced to flow along the flood plain some 200 miles before it can enter the Mississippi.

These natural levees form the only available sites where the lower river towns and cities, such as New Orleans, can be built.

LEVEE ALONG LOWER MISSISSIPPI

Artificial levees are often built to keep rivers from overflowing their flood plains. Such are the high levees along the Lower Mississippi and Sacramento Rivers.

Sometimes the flood plain of the main river is built up more rapidly than the tributaries can build theirs, so that they are dammed up as they enter the flood plain of the main stream and form a series of fringing lakes along its border. A fine example of this is found in the lower course of the Red River of Louisiana.

AN OLD RIVER

This river has done its work and has completed its activities.

When a river has graded itself and built its flood plain, its own active work consists largely in carrying off the materials brought to it by its side streams. Although these are now able to appropriate no new territory they continue to wear down the country and round off the divides till the whole region, unless reëlevated, is reduced to an almost level plain with its entire drainage system nearly

at grade. Most of the material now carried by the river is in solution, and there is but little erosion. The river has accomplished its life work, it has borne to the sea all the burden it has to bear, its labors are ended, it has reached old age.

Rivers in Dry Climates. — In a region where the climate is very dry, rivers are often intermittent in their flow. They contain water only after rains. Such rivers may dry up before they reach any other body of water, their water entirely evaporating or sinking into the dry soil. Their development is therefore somewhat irregular.

If the slopes are steep and there is little vegetation to protect them and hinder the quick run-off of the water, rivers flood very rapidly, eroding their channels and washing away their banks. Where they descend upon level ground they silt up their old courses and acquire new channels. Thus a river which for the larger part of the year is a mere brook may after a rain become a devastating torrent, bursting its banks and carrying destruction to settlements and farm lands along its course. It may even change its entire lower course.

Accidents in River Development. — A river may by some accident, such as the melting of ice during the Glacial Period, have had its supply of sediment greatly increased, causing it for a time to build up its valley floor instead of eroding it, thus forming a filled river valley. When the supply of sediment failed the river began cutting down the filled valley, leaving terraces along the sides to mark the successive levels at which it flowed. Such terraces are often very prominent along our northern rivers.

The region in which a river is situated may be *elevated,*

thus affecting its normal development and beginning a new cycle in its history. The elevating may take place over its whole drainage area or only over a part of it. It may take place at any time during the history of the river. If it takes place after the river has become old and is meandering on its flood plain, the river will begin afresh to cut down its valley. But as its meandering

River Terraces, Norway

The river is now cutting down its former plains, leaving terraces.

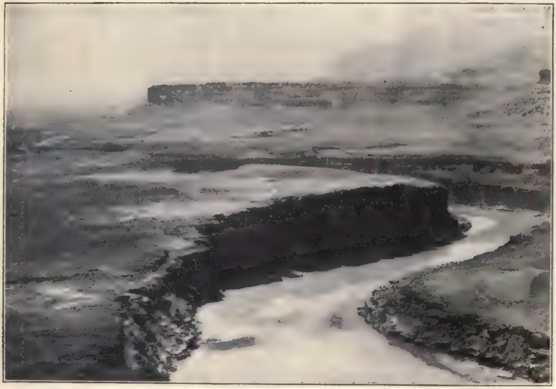
course has been established, the trench that it now cuts is not like that of a young river, but is a meandering trench, and what are called *intrenched meanders* are formed. This region will have the steep V-shaped valleys characteristic of a young region and the well-developed drainage and meandering rivers characteristic of a mature region.

It was the intrenched meandering valley of the Meuse River at Verdun which furnished the upland spur forti-

fications so successfully used by the French in repelling the German march up the valley.

Not only may a river be elevated, but it may be depressed. In this case its rate of erosion is diminished, and the river becomes marshy where the grade is low. Where the river valleys approach the sea they will be submerged or *drowned*.

These drowned river valleys form some of the finest harbors on the coast. San Francisco Bay, Narragansett



Intrenched Meander

Bay and New York harbor are examples of protected harbors due to the submergence of rivers. The mouth of the Hudson was formerly some seventy miles to the east of Long Island, that of the St. Lawrence to the east of Nova Scotia. In fact the Atlantic coast north of the Hudson furnishes innumerable examples of submerged river valleys.

Delaware and Chesapeake bays, where the early settlers each had a nice little sea inlet instead of a rough wagon

INTRENCHED MEANDERS.

road as his means of communication with his neighbors, are fine examples of submerged river systems. These drowned river valleys enabled the early settlers to penetrate easily into the country, and determined many of the early settlements, like Philadelphia, New York, and Providence.

Deltas. — When a river enters a body of quiet water, its current is gradually checked and it deposits its material

LAKE BRIENZ FROM ABOVE INTERLAKEN, SWITZERLAND

A rapidly eroding stream at the right has built a great delta dividing the ancient lake into two parts.

in somewhat the same way as on emerging upon a flat country. But here the deposition is more gradual and the slope of the deposited material less steep. The sedi-

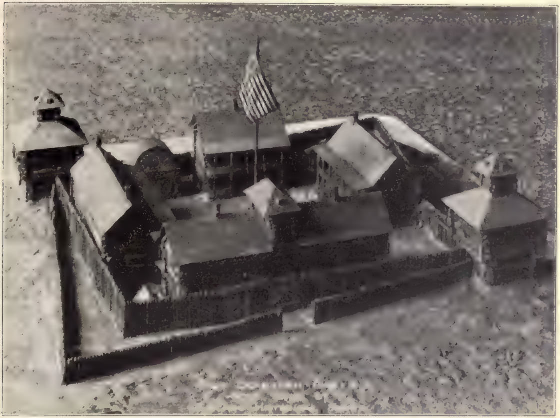
ment, too, is sorted by the water, and the finer material is carried far out from the river mouth. Formations of this kind are called *deltas*, from the Greek capital letter Delta (Δ), which has the shape of a triangle. Few deltas have this ideal shape, but there is a general correspondence to it.

Deltas have rich, fine-textured soils and are very fertile. The Nile delta during all history has been noted for its fertility. But they are treacherous places, as they are liable to inundations by the overflowing of the river at time of flood. Because they are pushed out into the sea, they are peculiarly exposed to the sweep of the waves in great storms. The delta of the Mississippi is more than 200 miles long and has an area of more than 12,000 square miles. The Po in historic time has built a delta more than 14 miles beyond Adria, a former port which gave its name to the Adriatic Sea.

Inland Waterways and History. — From earliest times rivers have played a most important part in the world's history. At first almost all human movement was along river valleys, as they offered the easiest routes of travel. Here, too, men found the fertile and easily worked land so necessary in their primitive agriculture. Thus their settlements were usually placed upon the banks of rivers. In war the river offered a means of defense, as the Tiber so often did to Rome.

Before the time of railways, rivers and lakes supplied almost the only means of inland commerce. In our own country the hundred and fifty miles of unobstructed riverway stretching from New York to the north was the great road from Canada and the Lakes to the sea, fought for persistently in French and Indian Wars as well as in the

Revolution. If in the Revolution the British could have obtained control of the Hudson, they would have effectually separated the colonists in the north from those in the



OLD FORT DEARBORN

Photographed from a model owned by the Chicago Historical Society. This fort on the Chicago River fostered the trading post that developed into the city of Chicago.

south and would probably have been able to crush each separately.

The Mississippi River served for years as the only artery of transportation from the interior of the country to the sea. When Spain held the mouth of this river and Congress was unable or unwilling to exert itself to obtain the privilege for American boats to pass to the sea, it seemed for a time that the sturdy colonists along the Ohio and Mississippi would either form an independent country

and fight for the privilege or else in some way ally themselves with Spain, so vital to them was the need of this waterway. In the Civil War vast amounts of blood and treasure were spent in fighting for the control of this river.

The majority of the great cities of this country owe their beginnings to facilities for water transportation. Many of them were first established as forts to control lines of water communication. Some of the most important of them were situated near portages from one water system to another. These naturally became trading posts; and as the white population increased, they developed into important settlements.

It was reasonable that these places should be among the first to enjoy railway facilities. If it happened they were situated on navigable systems that tapped regions of great natural resources, they became great trading cities. If they had the additional good fortune to be in the midst of great coal fields, manufacturing eventually added to their prosperity. If in addition to all these advantages, they lay in the natural lines of "long hauls" of developing railway systems, they grew with astonishing rapidity. Railways have also made possible the building of great "inland cities," but seldom is the growth of such cities discussed without the expression of wonder that such great results should be achieved in spite of the lack of water transportation.

The Improvement of Waterways. — Two thousand years before Christ the Babylonians connected the Tigris and Euphrates, thus showing that they realized the commercial advantages of improved waterways. More than a thousand years ago China began the extending of her waterways by

building a canal several hundred miles long. Since then almost every civilized nation has discovered for itself the need of increasing the usefulness of its natural waterways and has built artificial channels in order to extend cheap and easy facilities for transportation.

SINGEL CANAL, AMSTERDAM

A canal taking the place of the usual city street.

America has been slower to awake to the importance of this work than have the nations of western Europe with their denser populations. Many European countries are veritable networks of improved river channels and canals. The Seine carries the greater part of the ocean freight to and from Paris. The Rhine is used to the very limit of its navi-

gable course. More than ninety-five per cent of the Thames is open to navigation. A canal thirty-five miles long and twenty-eight feet deep conducts ocean-going vessels to and from Manchester. England alone has over two thousand miles of canals.

At first canals were built entirely for inland carriage, but later canals of international importance have been con-

PANAMA
An example of man's domination over nature.

structed to shorten the routes of ocean-going steamers. The Suez Canal reduced the distance by boat from England to India by about one third. The Kiel Canal, which connects the Baltic with the North Sea, has been of tremendous commercial and naval importance to Germany. The Panama Canal is a monument to American efficiency. It gives easy water transportation from the manufacturing

cities in the eastern and the central part of the United States to the Orient and to the western coasts of North and South America. It also allows the easy concentration of the United States Navy on either the eastern or the western coast.

It is to be hoped that the Erie Canal, connecting the Hudson River and the Great Lakes, will in the near future

CANAL

Two great oceans artificially united.

be made deep enough for ocean-going vessels. Another project of great importance is the proposed establishment, by canals and dredging, of a protected waterway from New England to southern ports. A network of inland waterways connecting Houston and New Orleans is (February, 1919) almost completed. By extending the Chicago Drainage Canal and dredging the Illinois River the Great

Lakes could be connected by navigable channels with the great Mississippi system. The dredging of portions of the Mississippi channel, the straightening of its course, and the building of additional permanent levees must some day be accomplished. Such improvements would render many cities along its banks veritable inland seaports.

Waterways such as these would relieve the great freight congestions that now so frequently occur on railroads and that will become more frequent with the increase of population. While water transportation is slower, it has the great advantage of being much less expensive. Many such improvements as have been mentioned have been strongly recommended by a Commission appointed by the Federal Government.

Sub-surface Water or Ground Water. — The rain that sinks into the ground descends slowly along the little cracks or between the particles of soil until it reaches a point where it can sink no further, or until it finds an opening through which it can flow out to the surface at a point lower than where it entered. Here it may ooze slowly out, or it may be concentrated in a spring.

If the water which comes to the spring has penetrated below the surface far enough to get away from the heating effect of the sun, it will be comparatively cool when it again emerges, and it will form a cold spring. If, however, in the region where the spring occurs the rocks are hot at the depth to which the water penetrated before it found a crack through which it could come to the surface of the land, then it will become heated and will form a hot spring.

As the crust of the earth is in many places composed of rocks in layers, the rain often falls upon the top of a folded

porous rock layer below which is a rock through which it cannot penetrate. The water will then accumulate

HOT SPRINGS IN THE YELLOWSTONE NATIONAL PARK, U. S. A.

throughout the porous rock. If this rock layer in another part of its extent is overlaid by an impermeable layer, its water is held in by the impermeable rocks above and below, and so is under hydraulic pressure. When a hole is made

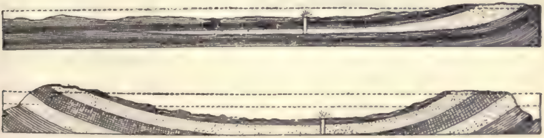


FIGURE 81

in the upper rock layer (Figure 81), the water will flow to the surface, and if the pressure is sufficient it may gush out of the hole.

Borings of this kind form what are called *artesian wells.* These are of great importance in many regions where it is difficult to obtain sufficient surface water. In some of our western states the water from artesian wells has been obtained in sufficient quantity for extensive irrigation. Although this water often contains minerals in solution, it is free from surface contamination and is therefore usually healthful for drinking.

Flowing Artesian Well

In some places the surface water penetrates into layers of rock which it can dissolve, such as salt or limestone. Here it forms caves and caverns, the solid material which occupied the place of the cave having been carried away in solution by the water. There are thousands of caves of this kind, but perhaps the most noted in this country is Mammoth Cave with its nearly 200 miles of underground avenues and grotesquely sculptured halls.

Sometimes the top of one of these caves is nearly eroded away, leaving a part of its old roof standing as a natural bridge, such as the natural bridge of Virginia or of Utah.

Supplying Water to Populous Communities. — The supplying of water to large communities has always been one of

man's great problems. Rome received its water supply by aqueducts from nineteen different sources, and some of these aqueducts were in use for fifteen centuries. The ruins of aqueducts built by the Romans are to-day among the most picturesque sights of the Italian and Spanish landscapes. Eighteen great water cisterns, remarkably well preserved, are the only remains of the once thriving city of

STRETCH OF A ROMAN AQUEDUCT NEAR NÎMES, FRANCE

Carthage on the North African coast. Near Tunis may be seen a stretch of the ancient aqueduct that brought water to these cisterns from the mountains thirty-five or forty miles to the south.

Springs and shallow wells have always furnished water to favorably situated rural districts and sometimes to small cities. Only in recent times have deep wells been sunk and water lifted from great depths. Modern large cities have seldom found supplies of water from underground sources adequate to the demands of manufacturing and

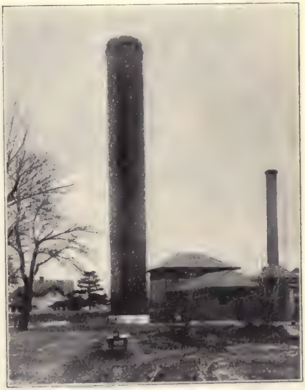
sanitation, although for many years London and Paris obtained a considerable part of their water supply from these sources.

Most of the great cities of the world are largely if not wholly dependent on near-by rivers and lakes for the water they use. Others have gone to the headwaters of streams in the hills or mountains, have conserved these uncontaminated waters in huge reservoirs, and have constructed great pipe lines to conduct the water to the cities' mains. The Los Angeles aqueduct brings water for a distance of 250 miles down over the foothills and through the desert. It is capable of supplying a population of 2,000,000. Such an engineering feat makes the ancient aqueducts look almost insignificant.

A Primitive Water Carrier in Mexico

How Water is Delivered through Cities. — Ancient cities had not the advantages of modern pressure pumps. They were, therefore, dependent upon gravity to bring water to them from sources higher than the community served. Whenever possible, modern cities obtain their water sup-

plies by the same method. But the modern city must do more than merely obtain water; it must deliver the water to every part of the city and to the top floors of the tallest buildings. Where cities obtain water from low levels they are compelled to use pumps, or pumps combined with standpipes or elevated reservoirs. The pressure of the water in these standpipes or reservoirs forces the water to faucets throughout the city. The higher the surface of the water is above the outlets, the greater will be the pressure (page 146). Largely on this account water from a standpipe or elevated reservoir has a weaker flow from faucets on upper floors than from those on lower floors of the same building.



A STANDPIPE

This furnishes water under high pressure for the use of a community.

Friction of running water against the pipes slows it up, and lowers the pressure. For this reason a reservoir can serve only a limited district. Large cities must provide many such reservoirs. The necessity of furnishing water to the top floors of very tall buildings and of fighting fire in these structures has compelled large cities to provide high-pressure pumps in addition to reservoirs. These pumps sometimes keep the water in the mains of the business sections at a pressure of 300 pounds, or even more, to the square inch.

Almost every one has noticed how the opening of a faucet in a home will reduce the force of the stream from a garden hose. This illustrates what may happen on a larger scale throughout a city system. The larger the number of faucets running at one time, the lower the pressure. For this reason, most cities try to prevent unnecessary use of water

FIRE-TUG IN ACTION

The "Graeme Stewart" on the Chicago River, throwing streams of water under tremendous pressure.

in homes during hours when business districts must be served and protected against possible fires. This is why many cities forbid the sprinkling of lawns during the busy hours of the day.

The Vital Importance of Pure Water. — Roman and Greek writers more than two thousand years ago emphasized the advantages of a *pure* water supply to a city. It is now

generally recognized that a modern city has no task more vital than that of guarding against contaminated water.

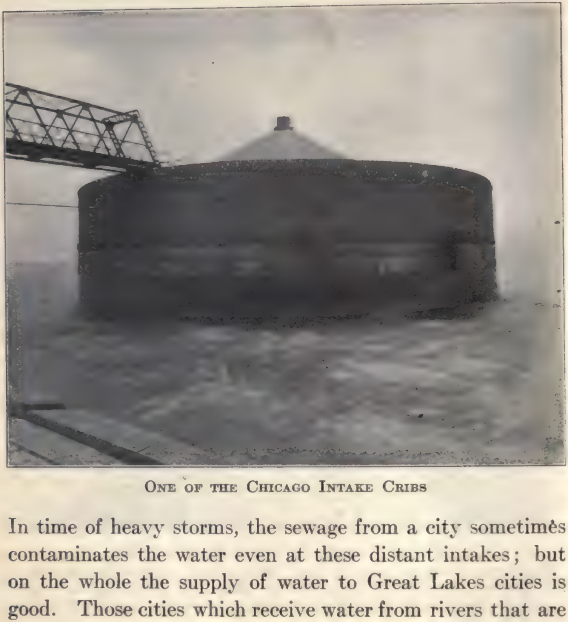
WILSON AVENUE WATER TUNNEL, CHICAGO

Photographed during construction. This tunnel is 12 feet in diameter, is hollowed out of solid rock 110 feet below the surface of the water, and extends eight miles from the pumping station on the north shore to the crib.

Those communities that use polluted water generally have a very high death rate from typhoid fever and from other intestinal diseases. Moreover the industrial efficiency of

a population is greatly reduced by sickness. Cities that receive their water supplies from uncontaminated uplands have a tremendous advantage.

Cities along the Great Lakes have run pipes out for miles to intakes, or *cribs*, in order to avoid shore contamination.



One of the Chicago Intake Cribs

In time of heavy storms, the sewage from a city sometimes contaminates the water even at these distant intakes; but on the whole the supply of water to Great Lakes cities is good. Those cities which receive water from rivers that are constantly being polluted by the sewage of communities farther upstream have a most serious problem, even though running water tends somewhat to purify itself. In many cases this problem has been admirably solved.

St. Louis, for example, is typical of many cities that perform marvels in transforming muddy river water into clear, healthful drinking water. The Missouri-Mississippi water as it enters the St. Louis intake contains mud and sand in suspension; coloring matter from decaying leaves, as well

ST. LOUIS FILTER PLANT

This building of reinforced concrete is 750 feet long by 135 feet wide.

as mineral matter, in solution; and disease bacteria. As the water passes slowly through settling tanks the heavier sediment falls to the bottom of the tanks. Chemicals are added. Some of these unite with the coloring matter, and others with some of the mineral matter, forming chemical compounds that are not soluble in water. These compounds may fall to the bottom of settling tanks or may be removed

by filtering through thick beds of sand and gravel. Finally small amounts of chemicals are added to kill the harmful

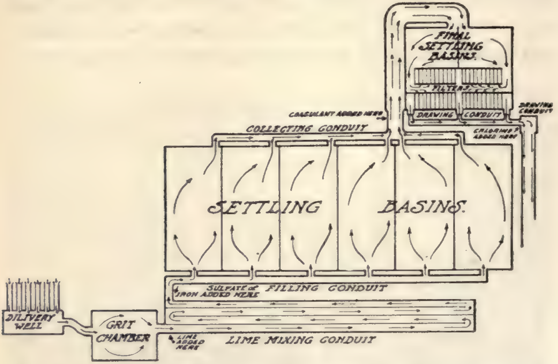


FIG. 82. — DIAGRAM SHOWING ST. LOUIS WATER PURIFYING PROCESS
The arrows show the course of the water through the plant.

bacteria, and the pure water is aërated and forced through the mains. None of the chemicals used makes the water harmful to drink or unpalatable to the taste

SUMMARY

When rain falls, some of it evaporates; some flows away on the surface of the land; some sinks into the ground, to return as springs or wells. The water which flows along the surface has a great effect upon the land. It forms the little streams which remove the surface water, the huge rivers which drain the country and form great arteries of trade, and the beautiful lake-reservoirs which hold back floods and offer easy transportation to ships.

But most important of all is the erosion caused by flowing water. It wears down the land's surface, bears away and deposits the eroded materials, cuts deep trenches, and forms broad valleys; it fills lakes and builds great deltas. Falls and rapids furnish water power for manufactures.

Rivers that have not yet widened their valleys and still have falls and rapids are called young; an old river is one whose bed has been worn smooth, and which has built for itself a broad level valley, through which it wanders, doing little if any erosive work. Rivers sometimes develop flood plains through which they wander in S-shaped meanders.

If the region of a river becomes elevated, the river may be revived, and if it is a meandering river, intrenched meanders will be formed. If a river region becomes depressed, the river will be drowned. These drowned river valleys form some of the finest harbors in the world. Many rivers build deltas when they empty into bodies of quiet water.

Rivers have always played a most important part in history, because river valleys offer the easiest routes of travel and furnish most fertile soils. Even in this day of railways, the largest cities of the world owe their great size to combined railway and water transportation facilities. So important is adequate water transportation that the countries of Europe have developed a wonderful network of artificial waterways and the United States contemplates spending millions of dollars in similar enterprises.

Springs and shallow wells furnish water to favorably situated rural districts and to some small communities. Most great cities must depend on surface water. Supplying water to populous communities is a most difficult undertaking. Water must be piped to homes and office buildings,

and forced to high levels. If the water is liable to contamination, expensive processes of purification and clarification are installed in the interest of public health.

Questions

Trace the probable journey of the water that fell near your home during the last heavy rain until it reached its journey's end.

Describe some of the effects of running water that you have seen.

Give the history of a river's development in a moist climate.

How do rivers in dry climates differ from those in moist climates?

Describe some of the accidents that are liable to happen during a river's development.

How have rivers affected history?

What has been man's part in the development of waterways?

What becomes of the water which sinks into the ground?

How is water supplied to the cities and towns near your home?

Why is a pure water supply so important?

CHAPTER VIII

WEATHER AND CLIMATE

The Warming of the Atmosphere. — The sun transmits both light and heat to the surface of the earth through the atmosphere. On the top of a high mountain the temperature is found to be colder than on the lower levels. The amount of sun radiation, technically called *insolation*, that falls upon a given surface on the mountain is about the same as that which falls upon an equal surface in the valley. If the heating effect is less it must be due to something besides the number of heat rays intercepted.

FIGURE 83

In the spring when gardeners wish to hurry the growth of their plants, they cover them with boxes, the tops of which are made of glass (Figure 83). It is found that the temperature within the boxes is higher than that outside.

The high temperature heat rays coming from the sun pass readily through the glass and are absorbed by the ground within the box, raising its temperature. The ground continues to keep warm after the sun ceases to shine because the heat given off by the soil under the box cannot readily pass out through the glass. Thus the heat of the sun is in a certain sense entrapped in the box or *cold frame*.

Now the atmosphere does for the earth what the glass does for the cold frame. The rays of the sun pass through the transparent atmosphere and warm the earth. When the earth reflects the sun's rays or gives up the heat it has absorbed, the atmosphere keeps this heat from immediately passing off into space and leaving the surface cold. Where the atmosphere is thin as on mountains, not so much of heat is retained and therefore their surfaces are cold and often covered with snow. Thus the atmosphere acts as a blanket and keeps in the heat from the sun, as blankets on a bed keep in the heat of the body.

Clouds help to hold in the heat. Farmers know that early frosts are likely to come on clear nights, but not on cloudy ones. On nights when there is likely to be frost, plants are covered with pieces of paper, smoky fires are built around cranberry bogs, and orchards are smudged, in order to blanket in the heat.

The atmosphere also acts as a sun-shield and protects the surface of the earth from the consuming heat of the sun. If there were no atmosphere, the earth's surface would become intensely hot during the day, when the sun shines directly upon it, and intensely cold at night; so that life could not possibly exist. It has been estimated that if there were no atmosphere, the mean temperature of the earth's surface during the day would be 350° F., and during the night −123° F. On the moon, where there is no atmosphere, there can be no life as we know it.

If a column of air is heated it becomes lighter and the atmospheric pressure at that point is lessened. The cooler air flows in below and forces the heated air to rise. Thus with the unequal heating of different places on the earth's surface, there is a constant tendency of air to move from

places of high pressure to places of low pressure; and so the air is constantly in motion, tending to transfer its heat and to equalize the atmospheric pressure. The greater the difference in pressure between places, the faster the movement of the atmosphere to overcome the difference.

The latitude of a place has much to do with the amount of heat it receives. As the sun becomes vertical to places north of the equator, the length of the day in the northern hemisphere increases, and the time that a place is in the sunshine is greater, so that it receives more heat from the sun. On the 21st of June all points within $23\frac{1}{2}°$ of the north pole, as at North Cape, have twenty-four hours of sunshine; and the amount of heat received at the pole during these twenty-four hours is greater than that received at the equator, where the day is only about half as long. But so much of the heat is absorbed by the melting of ice and the heating of the seas that have grown frigid during the six months of night that the sun's heating effect on the atmosphere is relatively small.

PICTURE TAKEN AT MIDNIGHT ON NORTH CAPE

The sun had not set even at midnight.

Although the latitude of a place has much to do with the amount of heat received, there are also many other things which affect its temperature. This will appear when we consider that Venice, Italy, with its mild and equable

WINTER SCENE IN VENICE

climate, is in almost the same latitude as Montreal, Canada.

As has been seen, the height above the sea makes a difference with the temperature, since there is less thickness of air above and therefore a thinner blanket to hold the heat. Then, too, the kind of soil affects the temperature. If the soil is sandy and there is little or no vegetation, it becomes rapidly heated in the daytime and radiates back the heat into the air very rapidly, thus making the temperature of the air near the surface very hot during the day; while at night, when the sun is not adding heat, it rapidly loses the heat acquired during the day, and so the temperature of the air becomes low. In the daytime on great sandy deserts the

WINTER SCENE IN MONTREAL
The famous Ice Palace, built entirely of blocks of ice.

heat is almost unbearable, but at night it is so cold that heavy blankets are needed to keep the traveler warm.

The nearness to the sea and the direction of the wind also greatly affect the temperature of a place. In some parts of the earth these are the principal causes in determining the temperature. Thus the temperature of the atmosphere at any place is not due to a single cause, but is the result of many and complex causes such as latitude, height, direction of prevailing winds, ocean currents, nearness to the sea, and kind of soil.

Graphic Method of Showing the Temperature of a Region. — It is often quite essential that the temperature over a considerable region should be known and a record of it made and preserved. This might be done by taking a map and writing their temperatures above the different places marked on the map. This would make a map full of small figures and very difficult to read.

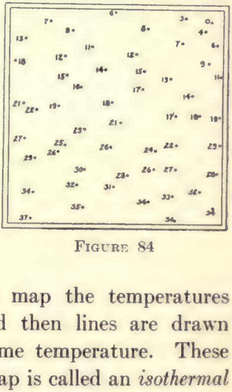


FIGURE 84

A much better method has been developed and is now almost universally used. In making this map the temperatures are first written on the map and then lines are drawn through places which have the same temperature. These lines are called *isotherms* and the map is called an *isothermal map*. By the use of such a map it is possible at a glance to determine the temperature prevailing at any place and to see the relation which this has to the temperature of other places on the map. As a rule the isotherms

are not drawn for each degree, but only for each ten degrees.

When the map has been constructed, copies are made in which the figures are left off and only the isotherms are preserved. In Figure 84 we have a plan before the isotherms are drawn, and in Figure 85 after the isotherms are drawn. Figure 86 is a typical isothermal diagram. If the map itself were sketched, it would be an isothermal map.

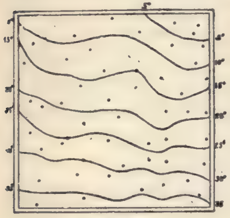


FIGURE 85

Maps recording barometric conditions are made in the same way as the isothermal maps, only their lines pass through places of equal barometric pressure instead of places of equal temperature. These lines are called *isobars*.

Weather maps are prepared by the United States Weather Bureau every day, on which are both the isotherms and isobars for that day. The data for these maps are telegraphed each morning from stations scattered all over the settled part of North America.

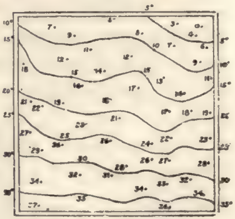


FIGURE 86

Weather Maps. — Expensive weather bureaus are maintained not only by the United States, but by all the other highly civilized countries of the world. Records are kept also by sea captains and by other observers throughout the world, and these are gathered together by scientific men and from them are

made charts of the weather conditions over the entire surface of the earth. Every year more and more data are being collected and these charts are becoming more and more reliable.

These charts are of great value, since they aid in the explanation of climatic conditions in different parts of the world. The results of the data thus gathered together have been of untold service to commerce and each year have saved many lives and a vast amount of wealth.

A SAILING VESSEL

Both the sailing vessel and the steamship are dependent for power on movements of the air — winds and drafts.

Circulation of Air. — The atmosphere is the circulatory medium of the earth, as blood is for the animal and sap for the plant. Without it the activities of the earth would stagnate. It scatters the seeds of plant life over the face of the earth. It carries water evaporated from the sea to the land, replenishes the underground reservoirs for man's use, and transports reserve supplies to the mountains for the use of cities, for power, and for irrigation. It cools the hot regions with the invigorating breath from the mountains and from the uniformly tempered sea. It warms the cold places by bearing to them the heat taken from the warmer ocean

waters and from the parched places of the earth. By its movements, it keeps the very fires of man's factories and engines burning, sweeps the smoke and foul air away from his cities, and bears his commerce across the sea.

Wind. — **Experiment 75.** — On a day when the temperature in the room is considerably higher than that outside, open a window at the top and bottom and hold a strip of tissue paper in front of the opening. Is there an air current, and if so, in what direction does it move at the top and at the bottom of the window? What causes "drafts" in a room?

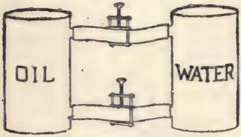


FIGURE 87

Experiment 76. — Procure two similar dishes about 15 cm. high and 5 or 6 cm. in diameter with short tubes of about 1 cm. in diameter opening out from near the top and bottom. Connect the bottom tubes of the two dishes with a tightly fitting rubber tube. Do the same with the top tubes. Place a Hoffman's screw upon each of the rubber tubes and screw it tight so that no liquid can flow through either tube. (If part of each rubber tube is replaced by a glass tube, the action in the experiment can be seen to better advantage.) Fill one of the dishes with colored water and the other with kerosene or some light oil.

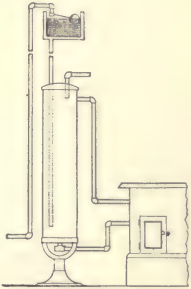
Release the Hoffman's screw upon the top tube and then the one at the bottom. Notice carefully what happens as the lower tube is allowed to open. The dishes are not now filled with oil and water respectively. In the transfer of the liquids, through which tube did each pass?


FIGURE 88

Experiment 77. — Fill a convection apparatus with water, putting in a little sawdust and mixing it well with the water. Heat one side of the tube and observe the convection currents set up.

In Experiment 76 the interflow from one dish to the other is due to the fact that the water is heavier than the oil and

runs under it and pushes it up so that the oil overflows into the dish that the water has left. The same thing happens in the atmosphere when from any cause the column of air above one place becomes heavier than that above another place. There will be under these conditions a transfer of air, along the surface, from the place where the pressure is greater to that where it is less great, and this movement of the air we call *wind*.



HOT WATER TANK

In this common appliance the heat of the stove causes the water to circulate in a way similar to that in which the air is caused to circulate by the heated surface of the earth. The hot water rises to the top of the tank from where the pressure of the cold water in the supply cistern will cause it to flow.

The wind on the surface of the earth is not usually in the same direction as that high up. The strength of the wind depends upon differences in air pressures. As the air pressure is measured by the barometer, the wind is commonly spoken of as due to a difference in *barometric pressure* or to the *barometric gradient*. Winds are named from the direction from which they come. A west wind is a wind that blows *from* the west.

If there were no other forces that affected the movement of the air, except the high and low pressures, the transfer would be in a straight line from one place to the other, and it could always be told in what direction the high and low pressures were, by direction of the wind. But obstacles like mountains and hills deflect the air currents. Chief among other causes which influence the direction of air movements is the rotation of the earth.

The Effect of the Earth's Rotation on Winds. — **Experiment 78.** — Revolve a globe from left to right and while it is revolving draw a piece of chalk from the pole toward the equator. Does the line as marked on the globe follow a meridian? What is its general direction in lower latitudes? While the globe is revolving, allow a drop of water to run from one pole to the other. Note the path it takes.

The rotation of the earth affects the direction of movement of all bodies free to move over its surface. Thus if

EFFECT OF PREVAILING WIND ON GROWING TREES

a current of air starts from the north pole to flow south, it will, as it goes along, tend to move toward the right, and so when it reaches middle latitude it is no longer moving south but southwest. Why this is so can be fairly well understood if the conditions of this moving body of air are considered.

As the earth is about 25,000 miles in circumference and turns on its axis once in 24 hours, a body situated at the equator is carried from west to east at the rate of about 1000 miles per hour, whereas a body at the poles simply turns around during a revolution. Thus as we go on the surface from the poles toward the equator, each point has an increasing west to east velocity.

A body of air, not being attached to the surface, will have this west to east velocity imparted to it very slowly by friction. Thus as it goes from higher to lower latitudes, it will lag behind particles on the surface which have this west to east velocity, and so will appear to have an east to west motion; just as to a person riding in a rapidly moving open car on a calm day there seems to be a strong "breeze." (That the "breeze" is produced by the motion of the car and not by movements of the atmosphere is shown when the car comes to a standstill.) The north to south movement of the air combined with its apparent east to west movement will give a northeast-southwest direction to the air current.

On the other hand, suppose an air current is moving from the direction of the equator toward the north pole. It has greater velocity toward the east than the part of the earth's surface it is approaching, and so instead of blowing due north it takes a northeast course. It can be seen then that whether an air current moves from the north pole toward the equator or from the equator toward the north pole, it will be deflected toward the right.

It can be proved mathematically that all freely moving bodies on the earth's surface are deflected toward the right in the northern hemisphere and toward the left in the southern hemisphere. This statement is called Ferrel's law.

Planetary Wind Belts. — As the air at the equator receives a large amount of heat, it becomes warm and light, while that near the poles is cold and heavy. The air would thus have a constant tendency to move along the surface of the earth toward the equator and in an upper current from the equator toward the poles, just as in the dishes where water and oil were connected. But this direct movement is affected by the rotation of the earth and by certain atmospheric conditions, so that between 25° and 35° both north and south of the equator there is an area of high pressure.

FIGURE 89. — WIND BELTS OF THE EARTH

From these areas of high pressure the surface currents move both toward the equator and toward the poles. On account of the earth's rotation the directions of these movements are not north and south but in the northern hemisphere northeast and southwest. Winds of this kind must occur on every revolving planet having an atmosphere; hence these winds are called *planetary winds*.

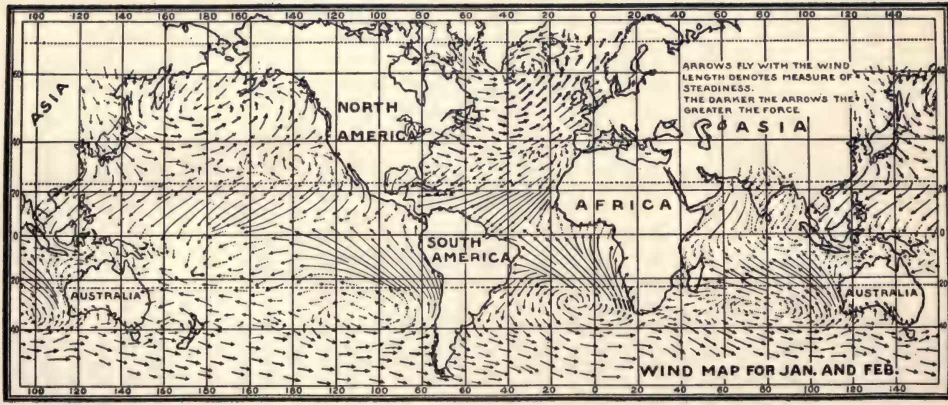
As the rotation of the earth and the heating of the air near the equator are conditions that do not change, among the most permanent things about our planet are the belts into which the wind circulation is divided. The change in the position of the *heat equator*, — the belt of highest temperature, — due to the apparent movement of the sun

north and south, modifies the conditions in these wind belts during the year. The planetary winds thus modified are sometimes called *terrestrial winds*.

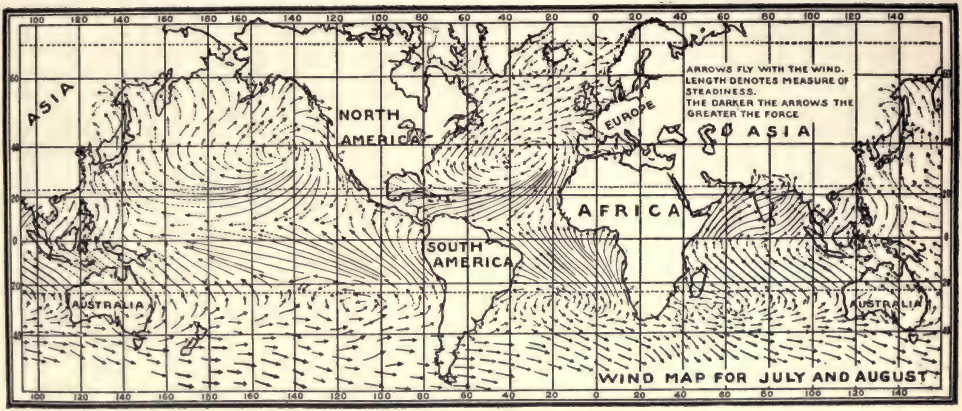
Wind Belts of the Earth. — Near the heat equator where the air is rising there is a belt of calms and light breezes called the *doldrums*. As the air here is rising and cooling (page 125), thus losing capacity to hold moisture, this is a cloudy, rainy belt of high temperature in which much of the land is marshy and the vegetation so rank and luxuriant that agriculture is exceedingly difficult.

Extending north and south of the doldrums to about 28° of latitude are belts in which constant winds blow toward the doldrum belt and supply the air for the upward current there. In the northern hemisphere these winds have a northeast to southwest direction and in the southern hemisphere a southeast to northwest direction. They are the most constant winds on the globe in their intensity and direction, and are called *trade winds*. Since they blow from a cold region to a warmer region, their power to hold moisture is constantly increasing and clouds and rains are not usual. The places where they blow are dry belts and in them are found the great deserts of the world.

On the poleward sides of the trade-wind belts lie the areas of high pressure already referred to. These are called the *horse latitudes* or *belts of tropical calms* and are rather ill-defined. The air is here descending and the surface movements are light and irregular. These, like the doldrums, are regions of calms. But unlike the doldrums, they are dry belts; since the descending air is increasing in temperature, owing to adiabatic heating (page 125), and thus its power to hold moisture is increasing. Therefore



WIND MAP FOR JAN. AND FEB.


ARROWS FLY WITH THE WIND.
LENGTH DENOTES MEASURE OF STEADINESS.
THE DARKER THE ARROWS THE GREATER THE FORCE
ASIA
NORTH AMERICA
EUROPE
AFRICA
SOUTH AMERICA
AUSTRALIA
WIND MAP FOR JULY AND AUGUST

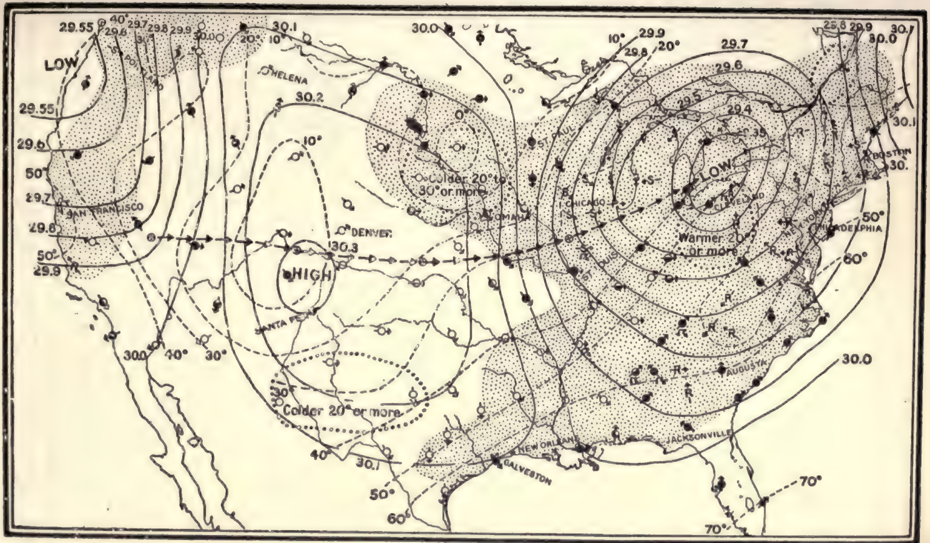
the tendency of the atmosphere in these belts is to take up moisture rather than to deposit it.

In the middle latitudes there is a belt of irregular winds which have a prevailing tendency to move from west to east or northeast. This general eastward drift of the air is constantly being interrupted by great rotary air movements having a diameter of from 500 to 1000 miles. These are called *cyclones* and *anti-cyclones*. In this region of the "westerlies," since the air tends to move from lower to higher latitudes, an abundance of moisture is usually supplied.

Cyclones and Anti-cyclones. — In the center of the large storm areas called cyclones, the barometric pressure is lower than that of the surrounding region, and so they are marked "Low" on the weather maps. Into these low pressure areas the air from all directions is moving. But the winds from high pressure areas do not blow directly into the center of a cyclone. On account of the rotation of the earth, any wind that starts toward the center of the cyclone area is deflected, in the northern hemisphere toward the right; in the southern hemisphere toward the left (page 219).

For example, in the northern hemisphere the wind from a point north of the cyclone center will be deflected to the west; the wind from the south will be deflected to the east. Since *all* winds blowing toward the cyclone area veer to the right of the cyclone center, they produce a great whirl in a direction opposite to the movement of the hands of a clock. (Figure 90.) In the southern hemisphere the cyclone rotates in a direction with the hands of a clock.

The rate at which the wind blows varies in different parts of the whirl, but is never very great. As these are areas


LOW
HIGH
LOW
HELENA
DENVER
SANTA FE
SAN FRANCISCO
PORTLAND
ST. PAUL
OMAHA
CHICAGO
CLEVELAND
BOSTON
PHILADELPHIA
NEW YORK
AUGUSTA
JACKSONVILLE
NEW ORLEANS
GALVESTON
Colder 20° to 30° or more
Colder 20° or more
Warmer 20° or more
29.55
29.6
29.7
29.8
29.9
30.0
30.1
30.2
30.3
29.5
29.4
10°
20°
30°
40°
50°
60°
70°

of ascending and cooling air they are storm areas. The extent of the precipitation varies in different parts of a cyclone according to the direction from which the ascending air has come. Note the direction of the wind and the rainfall area as shown on the map (page 225). Air which comes from continental interiors is dry, while that from great water areas contains much moisture, much of which it deposits when it cools by ascending (page 125). To these cyclones is due the larger part of the rain which falls in middle latitudes.

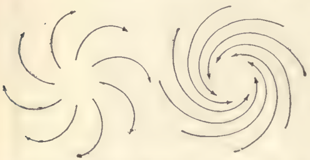


FIGURE 90. — DIRECTIONS OF WINDS IN AN ANTI-CYCLONE AND IN A CYCLONE

The anti-cyclone is just the opposite of a cyclone. The center of an anti-cyclone is a place of clear sky and high pressure. The air movement is slowly downward and outward from the center. (Figure 90.) These winds are dry, cool, and gentle.

Paths of Cyclonic Storms across the United States. — If you will watch the weather maps for several days in succession, you will find that cyclones or " Lows " move in a general eastward direction. The accompanying map shows the paths of a large number of cyclonic storms across the United States. It will be seen from this that although these paths vary considerably, yet the general direction is a little north of east. The movement of cyclones is in the general direction of the prevailing winds of the middle latitudes.

In winter time the average rate of motion of the cyclone across the continent is about 800 miles a day, while in summer it is only about 500. The velocity of the wind in the cyclone

itself is also much greater in winter than in summer, since the difference in pressure between the high and the low areas is much greater. The changes in temperature as the storms pass are greater in winter than in summer since the regions from which the northerly and the southerly winds flow in toward the center of low pressure vary more in their temperatures.

During the summer months people who live in the Mississippi Valley usually look to the south or southwest for the

clouds which bring rainstorms. From this direction come the moist northerly blowing winds (deflecting toward the east) from the Gulf of Mexico. The heaviest rain is always in the fore part of the eastward moving cyclone. The moisture laden winds coming from a warmer to a colder region and being forced upward in the cyclone deposit some of their moisture. In the western part of the cyclone are the winds blowing from northerly points. These come from

cooler into warmer regions and their capacity for moisture is increasing. As the center of the cyclone passes, therefore, the clouds generally begin to clear and the atmosphere begins to cool.

Sudden Weather Changes. — In middle latitudes there often occur, particularly in winter, sudden changes in the temperature of 20° or more in a few hours. In our own country, if the temperature falls 20° or more in twenty-four hours, reaching a point lower than 32° F. in the north or lower than 40° in the south it is known technically as a *cold wave*, and there is a special flag (Figure 91) displayed by the Weather Bureau to indicate the approach of such a change.

FIGURE 91

When these waves extend over the southern part of the country, they are very destructive to the orange groves and delicate crops and are known as "freezes." A notable freeze of this kind occurred in 1886 and did tremendous damage to the orange groves of Florida. So great was the effect upon this important industry throughout the orange belt that for years afterward the "freeze" was the date from which events were reckoned.

If the northwesterly wind which brings on the cold wave is accompanied by snow, it is called a *blizzard*, and on the plains and prairies, where the wind has a clear sweep, it is much dreaded. Cattle and men, when caught in it, frequently perish. In southern Europe the coldest winds are from the Siberian plains and are therefore northeasters. In the United States the cold area is at the southwest and rear of the cyclone, whereas in Europe it is at the north and front.

When, instead of the strong, cold, northwest winds which blow into the rear of a cyclonic area and in the colder seasons may produce a cold wave, there is a prolonged movement of highly heated air from the south into the front of the low pressure, as sometimes occurs during the warm months, the "hot spells of summer" are caused. The air is sultry, exceedingly hot and oppressive. Sunstrokes and prostrations from heat are common. The "hot winds" of Texas and Kansas, the Santa Ana of lower California and the siroccos of southern Italy are intensified examples of these winds. All sudden weather changes of this kind are due to atmospheric conditions related to areas of low pressure.

Thunderstorms. — Often on a hot, sultry summer afternoon large cumulus clouds are seen to rise and spread out till they cover the sky. The wind soon begins to blow quite strongly toward the cloud-covered area, the clouds moving in a direction opposite to the surface wind. As the storm clouds approach, a violent blast of wind, often called the *thundersquall*, blows out from the front of the storm. Soon flashes of lightning appear and thunder is heard. As the storm comes nearer, the rain begins to descend and for a short time, usually about half an hour, it rains heavily. Then the clouds roll away and the sky becomes clear with perhaps a rainbow to heighten the beauty of the clearing landscape.

Thunderstorms are caused by hot moist air rising over certain areas and causing an updraft, which is increased by the inflow and upward movement of air from the surrounding regions. The condensation of the moisture in the rising air quickly forms clouds, and these become charged with electricity. As the electrical charge increases, dis-

charges take place which cause lightning flashes. These discharges occur along the lines of least resistance and are often very irregular and forked. As tall objects are likely to offer good paths for the discharge, it is safest to keep away from trees and walls during a thunder-storm.

The air becomes greatly agitated by the lightning discharges and makes us aware of this by the noise of the thunder, just as the agitation of the air caused by the discharge of a gun is made apparent to us by what we call the noise of the report. The flash of lightning reaches the eye almost instantly after the electrical discharge; but since sound travels at the rate of about a mile in five seconds, there is often a noticeable lapse of time between the appearance of the flash and the sound of the thunder. The noise from different parts of the discharge will reach us at different times, and to this and the echoing from clouds or hills is due the roll of the thunder. To tell in miles the approximate distance of the flash, one has only to divide by five the number of seconds that elapse between the appearance of the flash and the noise of the thunder.

Frequently in the evening flashes called *heat lightning* are seen near the horizon. These are due to the reflection on clouds of flashes of lightning in a storm which is below the horizon. Thunder-storms occur sometimes in winter. They are very prevalent in the tropics.

Tornadoes and Waterspouts. — Sometimes causes like those which produce a thunder-storm are so strongly developed that the indraft is exceedingly violent and a furious whirling motion is produced. Such storms are called *tornadoes.* The warm, moist air rises rapidly and spreads out into a funnel-shaped cloud with the vertex hanging

toward the earth. In the center of the whirl the air pressure is much diminished and the velocity of the inrushing whirling wind is tremendous, being often sufficient to demolish all obstacles in its path.

A TORNADO
Notice the funnel-shaped cloud.

The length of the path swept over by a tornado is rarely over thirty or forty miles and the width generally less than a quarter of a mile. The rate of progress in the Mississippi valley is from twenty to fifty miles an hour, usually in a northeasterly direction. These storms are often wrongly called cyclones. When storms of this kind occur at sea, a water column is formed in the funnel-shaped part of the storm and they then receive the name of *waterspouts*.

Rainfall and Its Measurement. — **Experiment 79.** — Place a dish with vertical sides in a large open space so that the rim is horizontal and at a height of about one foot above the ground. Fasten the dish so that it cannot be overturned by the wind. After a rain, measure the water that has collected in the dish to the smallest fraction of an inch possible. This will be the amount of rainfall for this storm.

The amount of rainfall during the year varies greatly in different places. It amounts to nothing or only a few inches over some regions, as in parts of Peru where rain falls only on an average of once in five years. But in the Khasi Hills region of India it has been known to be over 600 inches; and over 40 inches, or about the average yearly

EFFECTS OF A TORNADO

The iron windmill was blown across the cellar and protected the people who had fled there for safety.

rainfall for the eastern United States, has been known to fall in 24 hours.

The rainfall in different parts of the earth has been carefully measured and maps showing its average amount prepared. As agriculture is largely dependent upon the amount of rain and the season of the year in which it falls, these maps tell much about the relative productivity of different regions of the earth. An annual total of eighteen or more inches is necessary for agriculture;

and this must be properly distributed throughout the year.

On examining a map of the mean annual rainfall (page 235), we see that there are large areas where it is not sufficient for agriculture without irrigation. Such areas are within the belts of dry winds or in continental interiors far from large bodies of water. The rain-bearing winds coming from the water are forced to rise and cool so that their moisture is deposited before reaching these interior regions.

WATERSPOUT SEEN OFF THE COAST OF NEW ENGLAND

The rainfall of a place depends largely: (1) upon its elevation, since most of the rain-bearing clouds lie at low altitudes; (2) upon the direction and kind of winds that blow over it; and (3) upon the elevation of the land about it. The sides of mountains toward the direction from which the rain-bearing winds approach will be well watered, while the opposite side may be a barren desert.

A cylindrical vessel having vertical sides, called a *rain gauge*, is used to determine the amount of rain. It is placed

in an open space away from all trees and buildings and after each rain the amount collected is measured. Snow is melted before it is measured. As a rule eight or ten inches of snow make an inch of rain.

If the temperature is below the freezing point, 32° F., when condensation takes place, the moisture of the air will form into a wonderful variety of beautiful six-rayed crystals. These gather into feathery snowflakes, which float downward through the air and often cover the ground with thick layers of *snow*. Although snow is itself cold, yet it keeps in the heat of the ground which it covers, so that in cold regions soil which is snow-covered does not freeze as deeply as that without snow. Therefore, to keep water pipes from freezing, it is not necessary to bury them as deeply in localities where snow is abundant as in places equally cold where snow seldom falls.

MAGNIFIED SNOW CRYSTALS

If raindrops become frozen into little balls in their passage through the air, they fall as *hail*. Hail usually occurs in summer and is probably caused by ascending currents of air carrying the raindrops to such a height that they are frozen and often mixed with snow before they fall. Sometimes hailstones are more than a half inch in diameter. They occasionally do great damage to crops and to the glass in buildings.

Sleet is a mixture of snow and rain.

Rainfall of the United States. — An examination of a rainfall map of the United States will show that the


AVERAGE RAINFALL
OF THE UNITED STATES

distribution of rainfall can readily be divided into four belts which, although gradually shading the one into the other, are yet quite distinct. These belts may be called the north Pacific slope, the south Pacific slope, the western interior region, and the eastern region.

In the north Pacific coast region the storms of the "westerlies" are common, particularly in winter, when the westerly winds are strong and stormy. The yearly rainfall here amounts to about seventy inches.

Salmon River Dam, Idaho
A typical irrigation dam in the United States.

From central California south the rainfall of the Pacific slope decreases until, in southern California, there is almost no rain in summer and the entire rainfall for the year averages about 15 inches. The high-pressure area of the dry tropical calm belt moves sufficiently far north in summer to take this region out of the influence of the wet westerlies and into that of the drier belt.

The western interior region, extending from the Cascade and Sierra Nevada mountains to about the 100th meridian, is dry over the larger part of its surface, since the winds have deposited most of their moisture in pass-

ing over the mountains to the west. On the mountains and high plateaus, however, there is a considerable fall of rain, as the winds are cooled sufficiently in passing over these to deposit their remaining moisture. In most of this region, as also in southern California, irrigation must be resorted to if agriculture is to succeed. The fall of rain on the mountains and high plateaus supplies rivers of sufficient size to furnish water for extensive irrigation, and so a considerable part of the area which is now practically a desert will in the future be reclaimed for the use of man. The government is at present engaged in extensive irrigation work in this territory.

From about the 100th meridian to the Atlantic Ocean there is a varying rainfall, but it is as a rule sufficient for the needs of agriculture. It gradually increases toward the east, moisture being supplied plentifully from the Gulf of Mexico and the Atlantic Ocean by the southerly and easterly winds. The rainfall is well distributed throughout the year and averages from thirty to sixty inches.

Weather Forecasting. — The data necessary for forecasting the weather are telegraphed to the Weather Bureau stations every day, and a record of them placed on the weather map. The observations recorded on these maps furnish the forecasters with all the information obtainable as to what the weather of the future is to be. It has already been stated that the dominant cause of our weather conditions, in middle latitudes, is the eastward movement of cyclones and anti-cyclones.

If the direction and rate of motion of these can be determined the weather of those places which are likely to come under their influence can be foretold with a good deal of

accuracy. If a cyclone were central over the lower Mississippi valley with an anti-cyclone to the west of it, we should expect that the southerly and southeasterly winds and rains to the east and southeast of the Mississippi would gradually change to fair weather and westerly winds with increasing cold, as the cyclonic area was replaced by the anti-cyclonic.

The rate at which the change would take place would depend upon the rapidity of the movements of the two areas of high and low pressure, and the order of change in the direction of the winds would depend, for any place, upon the directions taken by the centers of these areas. The direction of movement and the rapidity of movement of the cyclonic areas are, therefore, two of the chief factors which enter into the prediction of the weather. There is usually an increase in the intensity of the storm as the Atlantic coast is approached.

Climate. — The average succession of weather changes throughout the year, considered for a long period of years, constitutes the *climate*. Thus, if the average temperature of a place throughout the year has for a long period been found to be high, and the rainfall large and uniformly distributed, the place is said to have a hot and humid climate. The climate is a generalized statement of the weather. Two places may have the same average temperature throughout the year without having the same climate, as in one the temperature may be quite uniform and in the other very high at one season and very low at another. Many factors enter into the making up of a comprehensive statement of climate.

Effect of Mountains on Climate. — All over the world where people have the money and the leisure they are

accustomed to go either to the mountains or the seashore in summer in order to get where it is cooler. They might for the same purpose travel northward in the northern hemisphere, but they would need to go many times as far to get the same fall of temperature.

In summer one must ascend a mountain on an average about 300 feet vertically to get a mean fall of 1° F., whereas

TOP OF PIKE'S PEAK IN SUMMER

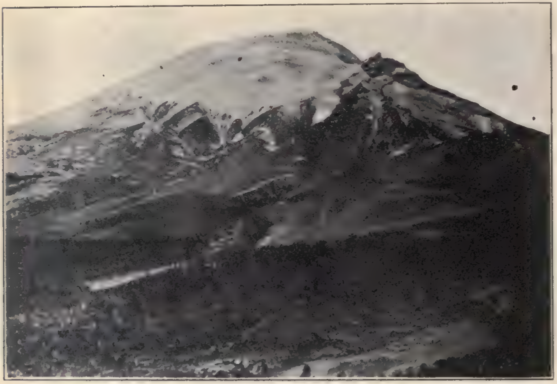
Notice the snow and the rocks broken up by freezing water.

one must travel over 60 miles north to get the same change. In winter one must ascend farther on the mountain and travel not so far north, to get a change of a degree. As one ascends a mountain it grows colder and colder. In ascending a high mountain in the tropics one passes through all the changes in climate which one would pass in going from the equator toward the poles.

As already stated, high mountains also affect the climate of the country near them. The windward side of moun-

tains is moist, since the moisture in the air is condensed in rising over them. On the lee side the country is dry, as the air which moves over it has already been deprived of its moisture.

The country on the lee side will also be subject to hot, dry winds like the chinook winds of the eastern Rockies and the foehn in Switzerland. As the moist winds pass

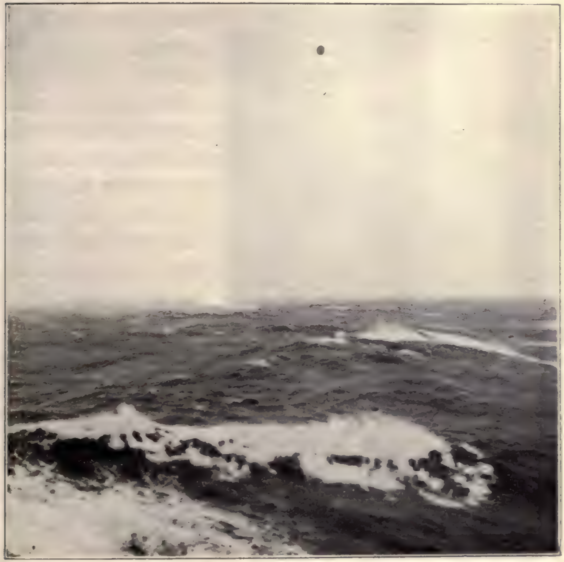


POPOCATEPETL

A snow-covered mountain in the tropics.

over the mountains their moisture is condensed. This raises their temperature so that it is above what it would normally be at the altitude reached. As these winds come down on the lee side of the mountain, the air is compressed and thus heated (page 125) so that on this side it is considerably warmer at the same altitude than on the windward side. Thus high mountains affect not only the rainfall, but the temperature changes of the region round about.

Effects of Large Bodies of Water on Climate. — We have learned that dark, rough surfaces absorb heat more rapidly than smooth, light, highly reflecting surfaces. We have also learned that a great deal of heat is required to raise



MID-OCEAN

Showing the constant motion of the water.

the temperature of water one degree — nine times as much as is required to accomplish the same result with an equal mass of iron. It is not surprising then that land surfaces heat up much more rapidly than water surfaces. How

much more rapidly cannot be stated with certainty, because soils differ greatly from one another. The darker or the coarser the soils, the more rapidly they absorb heat.

There is another very important difference between the heating of land and of water by the sun. The rays of the sun penetrate to a greater depth in water — especially clear water — than in soil. In addition to this, the water is constantly in motion and is communicating the heat from the surface to the cooler waters below. Thus the summer's heat affects the water many feet below the surface. This makes a lake or sea a veritable storage tank for summer's heat, yet the distribution of heat keeps the surface waters relatively cool in summer.

Palm Trees on Tropical Island of Tahiti

There is almost no range in the temperature of this island throughout the year.

The land, on the other hand, receives all of the sun's heat upon its surface. The top few inches of soil heat up very rapidly every summer's day, but soil immediately below this shallow crust never becomes very warm, and

does not show appreciable changes of temperature except with the changing seasons. At a very few feet below the surface the soil maintains a steady temperature summer and winter.

Surfaces that absorb heat rapidly also radiate it rapidly. A large percentage of the heat that the soil has absorbed during the day is given out to the atmosphere at night. But the water, slowly storing heat during the warm months and just as slowly giving it out during the cold months, has a steadying effect upon the climate of the land adjoining. On some islands of the sea, the range of temperature throughout the year is almost imperceptible, whereas in the interior of continents the average temperature of some of the summer months is more than a hundred degrees higher than that of some of the winter months.

Day and Night Effects along a Shore. — In the summer, the morning sun heats the soil increasingly until, by reflection and radiation from the land surface, the atmosphere above it is highly heated and expanded. The cooler air flows in from the lake or sea and displaces the lighter warm air. If the sun continues to shine, this landward breeze persists until late in the afternoon; but its effect is never felt many miles inland. At night when the rapidly cooling soil reaches a temperature below that of the water, the direction of the breeze is reversed.

Summer and Winter Effects along a Shore. — During the summer in warm climates, water is heated much less rapidly than the moist air above it and so it absorbs heat from the air day and night. This cools the atmosphere, and cooled air currents from above the water temper the heat of the adjoining land.

During the winter the water gives up its heat more slowly than the atmosphere. As it gradually yields the heat it absorbed during the summer, the air above it is warmed, and currents of this warmed air modify the temperature of the adjoining land. For these reasons a large body of water slows up the approach of warm weather in spring and of frosty weather in autumn.

In middle latitudes where the prevailing winds are westerly, these effects are naturally much more marked and dependable on the east shore of a body of water than on the west shore. In many places on the east shores of large lakes, delicate fruits can be raised because the steadying effect of these bodies of water prevents early " warm spells " alternating with frosts in spring, and delays the autumn frosts until the fruits have ripened. The tempering effects of warm ocean currents, combined with prevailing westerly winds, account for the mildness of climate even in high latitudes along the west *coasts* of North America and Europe, which are the east *shores* respectively of the Pacific and Atlantic oceans.

SUMMARY

The earth's atmosphere acts both as a blanket and as a sunshield to the earth's surface. In addition to this, it is the circulatory medium of the earth, without which there could be no life.

Winds and all movements of air are caused by unequal heating and consequently unequal atmospheric pressure at different places on the earth's surface. The prevailing directions of winds are also affected by the rotation of the earth. Certain winds common to all planets are called planetary winds; when modified by certain peculiarities of

the earth they are called terrestrial winds. Because of their constancy and their aid to traffic, some of these winds are called trade winds.

In middle latitudes there is a belt of irregular winds that have a prevailing tendency to move from west to east. This constant eastward drift of air is frequently interrupted by great rotary air movements having a diameter of from 500 to 1000 miles. These are called cyclones and anti-cyclones. The cyclone is an area of storm, and the anti-cyclone is an area of clear sky. These eastward-moving cyclones are responsible for most of the various changes in our weather. The two chief factors that enter into the forecasting of weather in middle latitudes are the direction of movement and the rapidity of movement of cyclonic areas.

Brief rainstorms accompanied by lightning are called thunderstorms. They are caused by local updrafts of air over hot, moist areas. When these local updrafts become exceedingly violent and of small diameter, tornadoes and waterspouts result.

When moist air cools, it cannot hold as much moisture as when it is warm, and so the excess falls as rain, hail, snow, or sleet. The rainfall varies from nothing at all in some places to over fifty feet a year in others. In the United States the north Pacific slope has a rainfall of about seventy inches a year; the south Pacific slope about fifteen inches; the eastern slope of the Rockies is very dry; and the Mississippi valley and the country to the east of it have a rainfall of from thirty to sixty inches.

The average succession of weather changes throughout the year considered for a long period of years, constitutes the climate. The climate of any section depends not only on latitude, but also upon altitude, nearness to large bodies

of water, kind of soil, direction of prevailing winds, and many other causes.

Questions

How does the atmosphere affect the temperature of the earth's surface?

How are weather maps constructed?

What is the cause of winds?

How are the winds of the earth influenced by its rotation?

In going from Boston to Cape Horn through what wind belts would a sailing vessel pass and how would her progress be affected by the winds in these belts?

Describe the wind directions and cloud conditions before, during, and after a rainstorm which you have experienced.

Describe the wind and cloud conditions of a thunderstorm.

Upon what does the rainfall of a place largely depend?

How is the rainfall of the United States distributed?

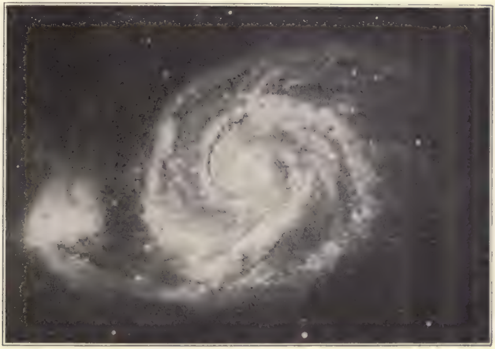
What is the effect of mountains upon climate?

How do large bodies of water affect the climate along their shores?

CHAPTER IX

THE EARTH'S CRUST

Changes in the Earth's Condition. — Several theories have been offered concerning the original conditions of the



SPIRAL NEBULA

The condition of one of the faint stars as revealed by the telescope. It is millions of miles in extent. Most scientists believe that the solar system was in such a nebular state as this ages ago.

earth, but as yet no one of them has been fully accepted. Almost all scientists agree, however, that the matter of the earth was once in a nebular, or gaseous, state. Uncounted ages afterward it came into a molten, or exceedingly hot liquid, condition; and it has been gradually cooling ever since.

Whenever borings have been made into the interior of the earth it has been found, after a depth has been reached where there is no effect from the heat of the sun, that the temperature rises as the depth increases. From this gradual increase in temperature, it must be that far down within the earth the temperature is very high. The pressure within the earth is so great, however, that rocks at great depths are probably not in a molten condition. If the earth had a liquid interior, the attraction of the other bodies of the solar system would cause changes in its shape; but it is as rigid as steel.

The outside cold part of the earth is called its crust. How thick this is, no one knows. This is the part of the earth that is of particular interest to us, for it is the only part that we are able to observe and study. It is impossible for us to conceive the eons of time that passed while the earth's exterior was cooling and changing, and coming into the condition in which we know it. Geologists think in tens and hundreds of thousands of years. The mountains that we see and even the continents we live on are the product of very recent changes, as geologists measure time, in the unimaginably long ages that reach back to the first gathering together of matter forming the earth.

Experiment 80. — When at home measure the greatest and least circumference of a large, smooth apple by winding a string around it and then unwinding and measuring the length of the string. Bake the apple. Measure its circumferences again. Are they greater or less than before? Is the skin of the apple as smooth as it was before?

There is every reason to believe that the interior of the earth is still cooling and contracting. Since the crust is already cooled, it has ceased to contract. Thus as the

interior shrinks, the crust must fold up in order still to rest upon the shrinking interior. The wrinkling of the skin of the baked apple as the interior of the apple cooled gives a faint notion of what has been happening to the crust of the earth through the ages. The cooling of the earth is so slow that the folding usually disturbs the surface but little

FOLDED STRATA

at a time. In recent hundreds of thousands of years, therefore, geological changes have usually taken place very gradually. These slow changes are still continuing, and the surface of the earth is being constantly modified.

Interchange of Sea and Land. — In many places at considerable distances from the ocean, sea shells have been found in the crust of the earth. Tree trunks are sometimes found at considerable depths in the sea, standing with

TEMPLE OF JUPITER NEAR NAPLES

Although it can be proved that this coast has been elevated and depressed several times, so gradual has been the movement, that the pillars have not been overturned.

OLD SEA BEACHES, SAN PEDRO, CALIFORNIA

Three old sea beaches can be distinctly seen on the promontory.

their roots penetrating the ocean floor just as they stood on dry land. It can be proved that an old temple near Naples, Italy, has stood above and then in the sea more than once since it was built.

Sometimes old sea beaches are found high above the shore and even at a considerable distance inland. Old

Old Rock Beach, Imperial Valley, California

This is many miles inland, but it was once a part of the coast of California.

river valleys are located by soundings under the sea, well out from the present mouths of rivers. From some markings on the coast of northern Sweden, it appears that the coast has risen about seven feet during the last 150 years. Observations along the coast of Massachusetts give reason to believe that this coast is sinking very slowly.

Facts like these show that the seacoast is not stable but is subject to upward and downward movements, some of which are slight, and others great.

Characteristics of Land Surfaces. — The surface of the land differs from that of the sea in being at least comparatively immovable. It is rough and irregular, and is composed of many different kinds of rocks and soils. For the larger part of its area it rises above the level of the sea, but in a few places it sinks below, as in the Salton Sea, a part of Imperial Valley, California, and near the Dead Sea in Palestine. Its surface is eroded by wind and water and is thus constantly but slowly changing its features.

Materials Composing the Land. — **Experiment 81.** — Obtain specimens of the igneous rocks, lava, obsidian, basalt, granite; of the sedimentary rocks, sandstone, fossiliferous limestone, conglomerate, peat; of the metamorphic rocks, gneiss, schist, marble, anthracite coal. Examine these carefully with the eye and with a lens, noting whether they have a uniform composition or are made up of different particles. Are the particles composing the rocks crystalline? Are they scattered irregularly or arranged in layers? Test with a file or knife-blade the hardness of the rock as a whole and of its different constituents. Try a drop of hydrochloric acid on the different rocks to see whether they are affected by it. Describe in a general way the characteristics of each specimen.

The composition of different land areas varies greatly. Many different kinds of rocks are often found crowded together, or it may happen that the same kind of rock covers a large area. There is no uniformity. The soil on top of the rock is also variable. In some places it contains the minerals which are in the rock below and in other places its composition is not at all dependent upon the bed rock.

The great variety of rocks of which the crust of the earth is composed has been divided into three great groups in accordance with the manner in which they were formed. These groups are *igneous*, *sedimentary*, and *metamorphic*.

The *igneous* rocks are those which have solidified from a melted condition. They may have solidified deep down within the crust, or on the surface, or somewhere between the depths and the surface. If these rocks cooled slowly, they will have a crystalline structure, as in granite, and if very rapidly, a glassy structure, as in obsidian. Their structure can vary anywhere between these two extremes. A common dark colored variety of this kind of rock is called *basalt*. There are many varieties of igneous rocks, but they need not be considered here.

GRANITE
Igneous rock formed deep below the surface of the earth.

FOSSIL-BEARING LIMESTONE
A sedimentary rock formed from sea shells.

The *sedimentary* rocks are those that are made by deposition in water. When rocks are worn away into fragments and these fragments are deposited in water they will, under cer-

tain conditions, harden into rocks. The shells and remains of sea animals also accumulate, and after a time consolidate into rock.

About four fifths of the land surface of the earth is composed of sedimentary rocks. They vary greatly in color, durability, and usefulness to man.

CONGLOMERATE
A sedimentary rock formed from old gravel beds.

The sandstones, which are composed of little grains of sand cemented together, are used for buildings and for many other purposes. The limestones, which are mostly made up of the remains of sea animals, are the source of our lime and are also used for building and for other purposes. The shales are finely stratified mud deposits often having many layers in an inch of thickness. These rocks are not crystalline. They are composed of fragments of other rocks or remains of plants or animals and usually occur in layers or strata.

Bituminous coal is sedimentary rock, formed from plants of ages ago which have been compressed and solidified by enormous and long-continued pressure.

The *metamorphic* rocks have a crystalline structure,

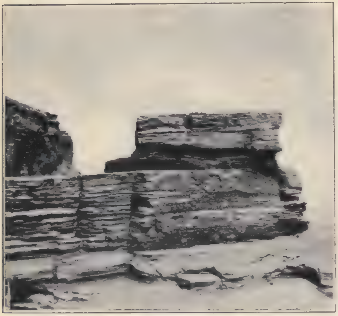
often contain well-formed crystals embedded in them and often bands of crystalline substances extending through them. These rocks are modified forms of either the igneous or sedimentary rocks. The original igneous or sedimentary rocks have been subjected to forces, such as heat and pressure, that have produced physical and sometimes chemical changes in them.

GNEISS
Probably metamorphosed granite.

Marble is crystallized limestone, and gneiss is generally a metamorphosed granite. Slate and mica-schist are greatly changed clay rocks, and anthracite coal is a metamorphosed form of bituminous coal. The rocks of this group are often hard to distinguish from igneous rocks.

Structure of Land Areas. — Not only do the land areas differ greatly in the kind of rocks of which they are composed, but also in the way in which these rocks are placed. Some of the rocks lie nearly in the condition in which they were originally formed, while others have been folded and warped and twisted. Vast layers of rocks have been worn away by the forces which are continually wearing away and removing the rocks at the surface of the earth, and thus rocks which were once at great depths below the surface have been exposed. Even granite rocks which were originally formed at a depth of thousands of feet below the surface now appear at the surface and are being quarried in many places.

The folding and warping of the rock layers, as shown by the picture on page 249, has brought some of the stratified beds which were originally horizontal into an almost vertical position, so that we now find at the surface the worn-off edges of these beds. The different kinds of rocks and the different positions in which the rock layers are presented to the forces which are active in wearing them away cause great variety in the forms of the surface features.



STRATIFIED ROCK

These layers have remained horizontal as originally formed.

Continental Shelf. — Around the border of the continents and of those islands which are near the continents, there extends, in some cases to a distance of two or three hundred miles, a gradually deepening ocean floor. This gradually deepening border is called the *continental shelf.* When this floor has reached the depth of about 600 feet, the gradual slant suddenly changes into a quick descent to the depths of the ocean, two or three miles.

Upon such shelves lie the great continental islands, like the British Isles and the East Indies. Continental shelves furnish the great fishing banks of the earth, such as the Grand Banks of Newfoundland and those around Iceland and the Lofoten Islands, where fishermen for ages have obtained vast supplies of fish. There is no equal area of

the earth where the life is so varied and the struggle for existence so great as on these shallow continental borders.

Here the mud and sand brought down by the rivers is spread out and the sedimentary rocks formed. It is the elevation of this shelf which has formed the low-lying coastal plains which border many of the continents. There is good reason to believe that the deep floors of the sea have never been raised into dry land, and that the vast extent of sedimentary rocks which make up the larger portion of the land has almost all been laid down in regions which were at the time continental shelves.

Coast Effects Resulting from Upward Movement of the Earth's Crust. — **Experiment 82**. — Tack enough sheet lead to a very rough board so that it will remain submerged when placed in water. Place the board in a shallow dish of water, lead side down. Taking the board by one edge, gradually lift this edge above the water surface. What kind of line does the water form where it meets the board? In what way would this line be changed if the board were smoother? If it were rougher? If the edge of the board is lifted higher, does the position of the water line change? Does its form materially alter?

Soundings show that a continental shelf has a comparatively smooth surface and a gentle slope. If the shelf is elevated, a strip of level sea bottom is added to the dry land, and the water will meet this new shore in almost a straight line. The material forming the shore, both above and below the water line, will be easily eroded since it has been recently deposited and has not had time to be consolidated into solid rock.

Waves rolling in from shore will strike the bottom of this gently sloping shelf at a considerable distance off shore. The water thus loses velocity, and deposits much of the solid

material it is carrying, forming a sand reef at some distance from the shore.

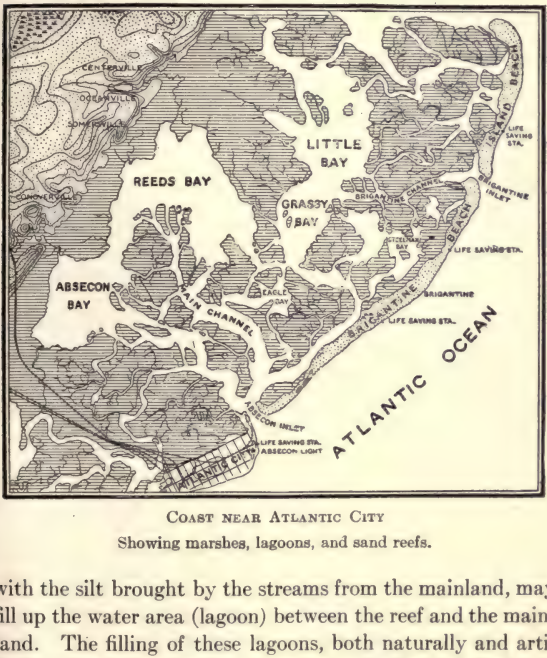
The waterways inclosed between sand reefs and mainland are often of sufficient depth to form protected routes for coastwise traffic. It is proposed artificially to extend and to develop certain of these water areas along the eastern coast of the United States so as to form a protected waterway

INLAND SEA CAVE AND BEACH
This coast has been recently elevated.

from New England to the southern ports. At present the low, almost featureless shore of this region, with its shifting sand bars and capes, makes coastwise navigation dangerous, although it is protected by many lighthouses and life-saving stations. The general set of the shore currents may singularly modify the outlines of the reefs, as is shown in the formation of the three much dreaded capes off the coast of North Carolina.

Sand hills, "dunes," form upon these reefs, building them

up and widening them. The sand reefs along the southern Atlantic and Gulf coasts have in some places sufficient width and height to accommodate large settlements. In time the sand blowing landward from these reefs, together



COAST NEAR ATLANTIC CITY
Showing marshes, lagoons, and sand reefs.

with the silt brought by the streams from the mainland, may fill up the water area (lagoon) between the reef and the mainland. The filling of these lagoons, both naturally and artificially, has greatly increased the habitable land of the earth.

Coastal Plains. — A coastal plain is a gradually emerged sea bottom, and so has shallow water extending out for a

considerable distance from its edge. Along the shore are marshes and lagoons bordered on their seaward side by sand reefs, where the winds have piled up the sand brought in by waves. In some places these sand reefs are so situated that they are valuable for habitation, as at Atlantic City, New Jersey, where a large summer resort has grown up, or along the coast farther south, where a sparse population finds its home on the broader reef.

A coastal plain increasing in width toward the south extends from New York to the Gulf. The western coast of Europe has a considerable plain of this kind. The Netherlands are situated on land which has been either reclaimed from the sea naturally in recent geological time or artificially by man in recent historical time. In the southern part this reclamation is largely due to the sediment brought down by the Rhine.

In the western part of the United States the coastal plain is not as well developed as on the Atlantic border. But the region about Los Angeles is a coastal plain, and almost all the characteristics of the broad eastern plain can be seen in traveling from the ocean to the coast mountains.

Coast Effects Due to Downward Movement of the Earth's Crust. — **Experiment 83.** — Cover a small board with a piece of thin oilcloth which has been most irregularly crumpled. Take the board by one edge and inclining it slightly gradually submerge it in a dish of water. What kind of a line does the water form where it meets the oilcloth? In what way would this line change if the oilcloth were more crumpled? If it were less crumpled? If the board is more submerged, does the position of the water line change? Why does its form materially alter?

Along a coast which has been *depressed*, the shore line has moved landward, and a surface rendered irregular by

erosion is lapped by the inflowing water. All the irregularities which lie below the water level are filled with water and the shore line bends seaward around the projecting elevations, and landward into the gullies and valleys. The tops of isolated hills now stand out from the shore as islands.

The river valleys which crossed the region now submerged reveal themselves only to the sounding line. Their

A Norway Fiord

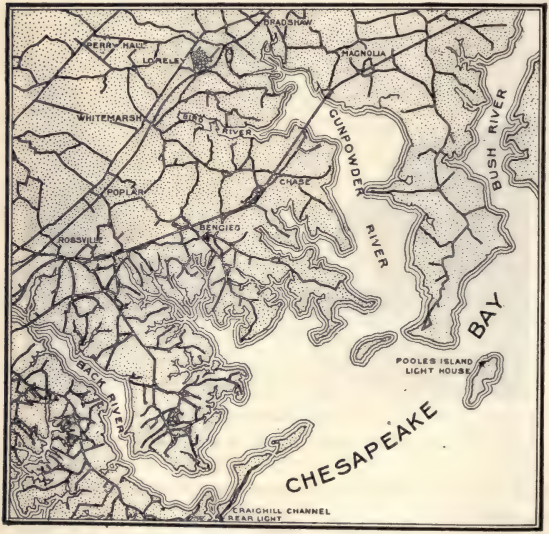
A result of downward movement of the earth's crust.

landward extensions form *estuaries* up which the tide sweeps far into the land. The unsubmerged portions of these valleys contain fresh-water streams, the size of which seems insignificant when compared to the size of the estuary. Sheltered coves and harbors abound, affording protection to all kinds of craft and fitting these coasts to be of great commercial importance.

The harvest of the sea replaces what might have been

the harvest of the land. Since the distance along the coast between two points is much longer than the straight line distance over the sea, the boat, not the wagon, becomes the important vehicle of travel.

The effect of a submerged and eroded coastal plain is seen in the Delaware and Chesapeake Bay region. Here



A Submerged Coastal Plain

the old river courses have been submerged, and the land between the rivers extends into the ocean in narrow, rather flat strips with many little inlets along the sides. Easy water communication is here possible to a considerable

distance inland and to almost every part of the land surface near the coast.

When the country was first settled, these water courses were most advantageous to the settlers, as the produce of the farms could be transported to sea-going ships with comparatively little difficulty, much more easily than would have been the case if it had been necessary to carry it by land. There was little need of building roads, as each farmer had a protected water highway to his door. Thus a part of this region was known as "Tide-water Virginia."

A NORWAY FIORD
Showing large vessels anchored in the deep water close to the shore.

In Norway the deep fiords conduct the sea from the island-studded coast far into the interior. Their sides rise steeply, sometimes for several thousand feet from the water's edge, and descend so steeply below it that large vessels can be moored close to the shore. Generally there is not sufficient level land along the sides of the fiord for building roads. The villages are usually situated where a side stream has built a little delta, or at the heads of the fiords where the unsubmerged portion of the valley begins.

It was such a coast as this which bred the ancient Northmen, to whom the Sea of Darkness, as they called the

Atlantic, was terrorless. While less favored and hardy sailors were dodging from bay to bay along the shore always in sight of land, they were pushing boldly west, guided

A NORWAY VILLAGE AT THE HEAD OF A FIORD

only by the beacons of the sky, and discovering Iceland, Greenland, and the American continent.

Hills and Mountains. — Irregular elevations of the earth's surface are called *hills*, or *mountains* when they are of considerable height. In the general use of these terms there is no exact line of separation. Elevations which in mountain regions would be called hills would in a flat region be called mountains. As a rule, elevations are not termed *mountains* unless they are at least 2000 feet high. But if the general elevation of the country is great, as in the lofty

regions of the Rockies, an elevation to be termed a *mountain* must rise to a striking height above the generally elevated surface, which is itself nearly everywhere more than 4000 feet above the sea.

Structure of Mountains. — Mountains are the results of deformations in the earth's crust, due to causes not

LOFTY MOUNTAINS
The high Sierras.

fully understood. The crust of the earth has been folded, pushed up, crumpled and in many ways distorted so that some portions have been elevated to great heights above sea level.

All lofty mountains have been elevated in comparatively recent geological time, but this of course means millions of years ago. If mountains now lofty were geologically old, they would long ago have been worn down, or *eroded*, by winds, rain, streams, avalanches, and glaciers. The

older mountains of the earth are all comparatively low, not necessarily because they were never elevated as high as the lofty mountains of to-day, but because their greater age has longer subjected them to erosion and thus reduced their height.

The central part of lofty mountains is composed of igneous rocks, but on the sides overlying these, sedimentary rocks are found. The Rockies, the Alps, and the Himalaya Mountains are of this kind.

THE MATTERHORN
A famous peak in the Alps.

Mountain Peaks. — In mountain regions the features which are often most impressive are the serrated peaks which rise above the main mass of the mountains. The shapes of these peaks vary greatly in different mountain

regions and tend to give individuality to the mountains. The peaks have been formed by erosion, and their peculiarities are due to the different kinds and positions of the rocks from which they have been carved.

The younger mountains which have not long been subjected to erosion do not show the peak and ridge structure. All these peaks are the result, not only of original uplift, but of subsequent carving.

THE TETON RANGE, IDAHO, U. S. A.
Mountains that have been eroded into sharp peaks.

Mountain Ranges. — As a rule mountains are found in *ranges*. The mountains in the range are by no means all the same elevation, nor is the range necessarily continuous, there being often gaps along its course. Neither were all ranges in a mountain region elevated at the same time. Those which make up the mountain region of the western United States differ much in the time of their elevation.

Young Plateaus. — Sometimes large areas of horizontal rock are elevated high above the sea, forming lofty plains whose surfaces are often irregular, owing to previous erosion. Such areas are called *plateaus*. The descent from a plateau to the lower land is usually steep. Areas of this kind, where streams are present, suffer rapid and deep erosion, since the grades of the streams are steep because of the elevation.

If there is not much rain there will be few streams, and these will have deep and steep-sided troughs. Such troughs render the area very difficult to cross. The valleys are too narrow for habitation or for building roads, and the deep troughs of the streams are too wide to bridge. Thus the uplands are isolated.

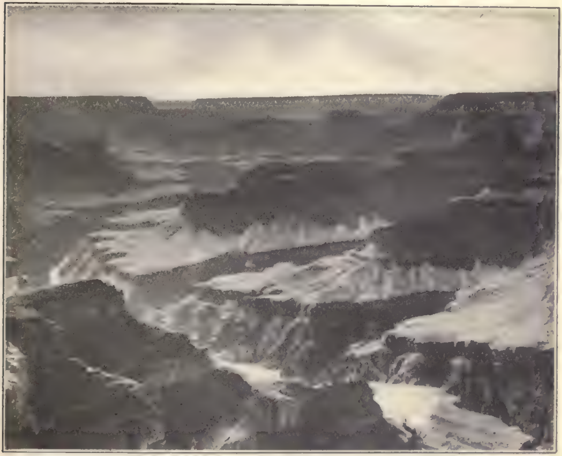
If these high areas are in a warm latitude, they are desirable for habitation on account of their cool climate, due to the elevation; but if in temperate latitudes, their bleak surfaces are too cold.

As the river troughs wear back, the harder rocks stand out like huge benches winding along the course of the rivers. From the different benches slopes formed from the crumbling of the softer strata slant backward. Thus the general outline of the stream sides will be something like that of a flight of stairs upon which a carpet has been loosely laid.

An excellent example of a region of this kind which has been eroded by a strong river gaining its water from a distant region is that of the Colorado Cañon Plateau. Here is found the grandest example of erosion on the face of the earth. The rocks are of various colors; the gorge is nearly a mile deep and in places some fifteen miles in width. Words are inadequate to express the grandeur of the panorama spread out before one who is permitted to see this

gigantic exhibition of the results of erosion. Wonderful, grand, sublime, are mere sounds which lose themselves in the ears of one who looks out upon this overpowering display of Nature's handiwork.

The region is very dry, and the river receives few and short branches for many miles of its course. The valley



COLORADO PLATEAU

The Colorado River has cut a deep cañon through this high plateau.

is widening much more slowly than it would if this were a land of considerable rainfall, and as yet the river fills the entire bottom of the gorge. The valley is in the early stages of its development and the erosive forces have just begun the vast work of wearing down the region. The side streams are small and the interstream spaces broad.

Dissected Plateaus. — If a plateau has been elevated for considerable time in a region of abundant rainfall, the streams extend their courses in networks, thoroughly dissecting the area and leaving between their courses only narrow remnants of the upland. The valleys are still deep, but the intervening uplands are of small extent. Traveling over the region in any direction except along

THE ENCHANTED MESA, NEW MEXICO
With old Indian village in foreground.

the stream courses is a continual process of climbing out of and into valleys.

There is very little level space that can be used for cultivation, and on account of the steepness of the slopes it is very hard to build roads. The river valleys are so narrow that unless the roads are perched high up on the sides, they are liable to be swept away at the time of flood. Farming in these regions is very discouraging because of the diffi-

culty of transporting crops and of finding anything but a steep side hill on which to grow them.

Railroads can get through only by following the principal valleys, and here, on account of the narrowness, the

A BUTTE

engineering of the roads is difficult. Unless the region is rich in minerals, it can support only a small population, and that will of necessity be poor. If the forests are cut off, the soil rapidly washes down the hillsides and leaves naught but bare surfaces. Regions of this kind are found in the Allegheny and Cumberland plateaus, extending from New York to Alabama.

Old Plateaus. — If a plateau remains elevated for a great length of time, the rivers are able to widen their valleys and wear away all the interstream spaces, except where these are very broad. Thus the rivers bring the whole surface down to a comparatively low level, with here and there a remnant which has not been worn away, but which shows in its steep sides the edges of the rock layers which

AN INDIAN HOGAN

formerly spread over the whole region. If these residual masses are large, they are called by the Spanish name *mesas*, meaning tables, and if small, *buttes*, from the French word which means *landmarks*.

Some of these mesas are so high and so steep that it is impossible to climb them, and others are simply low, flat-topped hills. A traveler in New Mexico and Arizona will see many of these mesas, which, like the lonely Indian

huts or *hogans*, are but scattered remnants of what were formerly widespread.

On old plateaus travel is easy. There are no deep valleys, and one can easily pass around the mesas, which only add charm to what would otherwise be a most monotonous

CLIFF DWELLINGS, ARIZONA
A protected retreat in a mesa.

landscape. When these mesas are high, they are sometimes occupied by a few Indian tribes who have fled to them for protection, as the medieval barons when hard pressed fled to their isolated castles.

The Great Plains of the United States. — No exact distinctions may be made between plains and plateaus. Some surfaces partake of the nature of both. West of the Mis-

INDIAN HIEROGLYPHICS CUT ON THE STEEP WALL OF A MESA

sissippi River the open prairies of the north and the coastal plain of the south gradually merge into a broad extent of territory that slopes upward until it meets the eastern Rocky Mountain plateau five or six thousand feet above sea level. The slope of this area is so gradual that the change of elevation is hardly noticeable, and so it is called the Great Plains. It is probable that this vast expanse

A HIGH DRY PLAIN IN CENTRAL NEVADA

of land was tilted upward when the crust of the earth was folded upward along the great continental divide.

The elevations are either flat-topped hills, the strata of which are slightly inclined and correspond in position to those found in the plain beneath, or they are masses of igneous material which appear to have been thrust up through the rock surrounding them. In the former case the elevations are simply remnants of the layers of rocks which once extended over the country, but which have now been eroded away over the larger part of it; in the latter case they are the igneous masses which have withstood erosion.

SUMMARY

Almost all scientists agree that the matter of the earth was once in a nebulous state. From this it came into an exceedingly hot liquid condition and then into a solid state. The interior of the earth is still hot, but the outside part, or crust, is cold. As the interior of the earth is still cooling and contracting, the crust must fold in order still to rest on the shrinking interior. Thus the surface of the earth has been slowly changing through the ages, and it continues to be modified. For example, the sea coast is not stable but is subject to upward and downward movements. The surface of the land is rough and irregular and different land areas vary greatly in composition, in the warping and folding of rock layers and in the positions of these layers. The rocks of the earth's crust are divided into three groups: igneous, which have solidified from a melted condition; sedimentary, which are made by deposition in water; and metamorphic, which are forms of igneous or sedimentary rocks that have been modified by natural forces.

The ocean floor near continents slopes off gradually until it reaches a depth of about 600 feet, when it suddenly changes to a sheer depth of two or three miles. This gradually deepening border is called the continental shelf. Upon such shelves lie the great continental islands and fishing banks. The upward movement of these continental shelves gives us our coastal plains and has greatly increased the habitable land of the earth. The depression of continental borders has given us our estuaries, deep harbors, and conveniently navigable coasts.

Mountains are the result of folding, pushing up, crumpling, and other distortions of the earth's crust that have occurred during ages of change. Mountains are usually found in ranges and the peaks are the results of erosion. Large areas of horizontal rock that have been elevated high above the sea level are called plateaus. If subject to great erosion, plateaus eventually become dissected and finally worn down to a comparatively low level, with only occasional mesas and buttes rising here and there. The Great Plains are a vast sloping surface that was probably tilted upward when the crust of the earth was folded along the great continental divide.

Questions

What changes have taken place in the earth's condition?

To what great classes do the rocks in your neighborhood belong?

For what would you look if endeavoring to determine whether a coast had been elevated or depressed.

What advantages does an elevated coast furnish its inhabitants? A depressed coast?

To what is the height of mountains due?

Describe the characteristics of a young plateau.

Why do not dissected plateaus attract a dense population?

What are the characteristic features of an old plateau?

CHAPTER X

PREPARATION OF THE EARTH'S SURFACE FOR PLANT LIFE

Changes in the Earth's Surface. — The surface of the earth is constantly changing. In fact change is the funda-

A RECENTLY COOLED LAVA SURFACE[1]

A surface probably somewhat like the original surface of the earth.

mental law of life. There are forces constantly building up and other forces just as steadily tearing down. Sometimes

the same forces are doing both. It is impossible to tell which set of forces is of the greatest service to man; because without either, life could not continue.

It is believed that the whole surface of the earth originally hardened from a molten condition, just as lava from a volcano hardens when it cools. We have seen that the waters of the sea and the waters that run over the land are wearing away

Rock Split by Roots of Tree

the rocks, grinding them together, pulverizing them, and carrying the wreckage to other places. This eroding must have begun as soon as the earth's crust became cool enough for the waters of the atmosphere to condense.

It is necessary, however, to take into account not only the power of water "to wear away the stones," but also its ability to hold many substances in solution and to carry them away to places where the water is evaporated and the dis-

solved substances deposited. The tremendous power of freezing water, the weathering power of the atmosphere, the wearing and transporting power of the wind, the scouring and pulverizing power of moving ice, and the never-ending processes of growth and decay have also greatly affected the earth's surface.

Experiment 84. — Allow a test tube filled with water and tightly corked to freeze. What happens? If the temperature of the air is not cold enough, place the test tube in a mixture of chopped ice and salt, or better, chopped ice and ammonium chloride (sal ammoniac), and allow it to remain for some time.

Water getting into the cracks of rocks and expanding when it freezes splits them apart and aids much in their destruction. Plant roots penetrate into the crevices of rocks and by their growth split off pieces of the rock. Water, especially when it has passed through decaying vegetable matter, has the power of dissolving some rock minerals. Certain minerals of which rocks are composed change when exposed to the air somewhat as iron does when it rusts.

Rock Weathering. — **Experiment 85**. — Weigh carefully a piece of dry coarse sandstone or coquina. Allow this to remain in water for several days. Wipe dry and weigh again. Why has there been a change in weight?

Experiment 86. — Fill a test tube or small glass dish about half full of limewater, made by putting about 2 ounces of quicklime into a pint of water. Blow from the mouth through a glass tube into the limewater. There is formed in the limewater a white substance which chemists tell us is of the same composition as limestone.

Experiment 87. — Continue to blow from the mouth for a considerable time through a tube into a dish of limewater. The white substance disappears. The carbon dioxide of your breath dissolved in the water, forming a weak acid, and caused the change.

Now if we heat the water, thus decomposing the acid and driving out the gas, the white substance again appears.

Oxygen, carbon dioxide, and moisture are the chief weathering agents of the atmosphere. Rocks which are exposed to the atmosphere, especially in moist climates, undergo decomposition. If the climate is warm and dry, rocks may

Rocks Weathering and Forming Steep Slopes

stand for hundreds of years without apparent change, whereas the same rock in another locality, where the weather conditions are different, will crumble rapidly. A striking example of this is found in the great stone obelisk, called Cleopatra's Needle, which was brought from Egypt to Central Park, New York, some time ago. Although it had stood for 3000 years in Egypt without losing the distinctness of the carving upon

it, yet in the moist and changeable climate of New York it was found necessary within a year to cover its surface with a preservative substance.

Not only do different climates affect differently the wearing away of rocks, but different kinds of rocks themselves vary much in the rate at which they crumble. It has been found that while marble inscriptions, in a large town where there is much coal smoke and considerable rain, will become illegible in fifty years, that after a hundred years inscriptions cut in slate are sharp and distinct.

CLEOPATRA'S NEEDLE, CENTRAL PARK, NEW YORK

Where the temperature varies greatly during the day the expansion and contraction due to the heating and cooling sometimes cause a chipping off of the rock surfaces.

Wind Erosion. — The artificial sand blast is in common use. In it a stream of sand is driven with great velocity upon an object which it is desired to etch. In nature the same kind of etching is done by the wind-blown sand.

WIND-CUT ROCKS, GARDEN OF THE GODS, COLORADO

These rocks have been fantastically cut by wind-blown sand.

The glasses in the windows of lighthouses along sandy coasts are sometimes so etched as to lose their transparency. Rocks exposed to the winds are carved and polished; the softer parts are worn away more rapidly than the harder parts, just as in all other forms of erosion. In certain regions where the prevailing winds are in one direction, one side of exposed rocks is found to be polished, while the other sides remain rough.

Wind Burying and Exhuming. — In exposed sandy regions where there are strong winds, objects which obstruct the movement of the air cause deposition of the transported sand just as obstructions in flowing water cause sediment to be deposited. And just as sand bars may be deposited by a river

A TREE BEING DUG UP BY THE WIND

and then carried away again, owing to a change in the condition of the river's load, so forests and houses in sandy regions are sometimes buried, to be uncovered again perhaps by a change in the load carried by the wind.

Sand Dunes. — Sand-laden wind generally deposits its burden in mounds and ridges called *sand dunes* (page 258).

A Forest on Cape Cod, Massachusetts, Being Buried in Wind-blown Sand

When once a deposition pile begins, it acts as a barrier to the wind and thus causes its own further growth. In great deserts where the wind is generally from one direction, these sand dunes sometimes grow to a height of several hundred feet, but usually they are not more than 20 or 30 feet high.

They generally have a gentle slope on the windward side and a steep slope on the leeward side. The sand is continually being swept up the windward side over the crest, thus causing the dune to move forward in the direction in which the prevailing wind blows. (Figure 92.)

Almost no plant life can find lodgment in these shifting sand piles, and so the wind continually finds loose sand on which to act, and a dune country is always a region of shifting sands. As the dunes move in the direction of the prevailing wind they sometimes invade a fertile country, so that it becomes necessary if possible to find a way to check their movement. This has been done in some places by planting certain kinds of grasses capable of growing in the sand and thus protecting the sand particles from the action of the wind.

FIGURE 92

Sand dunes are found along almost all low sandy coasts, and they render difficult the building and maintenance of roads and railroads to many beach towns.

Wind-borne Soils. — Whenever the wind blows over dry land, particles of dust and sand are blown away and deposited elsewhere. The interiors of our houses often become covered with dust blown from the dry streets. Even on ships at sea, thousands of miles from land, dust has been collected.

In volcanic eruptions great quantities of dust are thrown into the air and spread broadcast over the earth. On the highest and most remote snow fields particles of this dust have been found. In the great eruption of Krakatoa, dust particles made the complete circuit of the earth, remaining in the air and causing a continuance of red sunsets for months.

Sand is not carried so far as dust, but at times of strong wind it is often borne for long distances. Even houses,

trees, and stones of considerable size may be lifted and moved by a fierce wind storm. The wind-swept detritus has been known even to obstruct and modify the course of streams. Where the wind blows dust constantly in one direction, deposits of great thickness are sometimes made.

In Kansas and Nebraska there are beds of volcanic dust, reaching in some places to a thickness of more than a score of feet, and yet there are no known volcanoes either past or present within hundreds of miles. In China there is a deposit of fine, dustlike material, in some places a thousand feet thick, which is thought by some to be wind blown. This forms a very fertile and fine-textured soil and supports a great population. Many of the inhabitants of the region live in caves dug in the steep banks of the streams, so firm and fine textured is the material. Wind deposits of this kind are called *loess beds.*

Ice as a Soil-builder. — The agent that has had most to do with preparing the soils of the great grain-bearing regions of Russia, northern Europe, Canada, and the United States is ice. It has worn down and pulverized the rocks into soils, has mixed and transported the soils from regions farther north, and has laid them down in the irregular surfaces which form the fertile agricultural fields of these regions at the present day. Ice has been the master soil-builder of much of the tillable land of the world, and deserves careful consideration.

Snow in Winter. — When the temperature of the air falls below the freezing point, its moisture congeals into little flake-like crystals and falls as *snow.* Where the cold is continuous for a considerable time, the snow may accumulate in deep layers over the ground. If the heat of

the summer is not sufficient to melt all the snow which falls in the winter, then the layers of snow will increase from year to year.

To have this occur the temperature for the whole year need not be below the freezing point, but the heat of the summer must not be sufficient to melt all the snow which

Mount Hood, Cascade Range, Oregon

A beautiful old volcanic cone which is continually covered with snow.

fell in the colder season. Lofty mountains, even in the tropics, have their upper parts snow-covered. In the far north and the far south the line of perpetual snow falls to sea level, inclosing the mighty expanse of the Arctic and the Antarctic snow fields.

Glaciers. — Wherever there is not enough heat in the warm season to melt the snow which accumulates during

the cold season, a thick covering of snow and ice will in time be formed. The ice is due to the pressure exerted on the lower layers by the weight of the snow above and to the freezing of the percolating water which comes from the summer melting of the upper snow layers.

Although ice in small pieces is brittle, in great masses it acts somewhat like a thick and viscid liquid. It conforms itself to the surface upon which it lies, and under

SNOW FIELDS AT THE HEAD OF A GLACIER

the pull of gravity or pressure from an accumulating mass behind, slowly moves forward, resembling in some ways thick tar creeping down an incline or spreading out when heaped into a pile. Such a moving mass of ice is called a glacier. The exact manner of glacial movement, however, is not fully understood.

In mountain regions where the snow holds over through the summer, the wind-drifts and the snow-slides carry great quantities of snow into the upper valleys, until ever

accumulating masses of snow and ice, hundreds of feet thick, are formed. The ice then slowly flows down a valley till a point is reached where the melting at the end is equal to the forward movement. An ice stream of this

Gorner Glacier

A typical Alpine glacier.

kind is called a *valley glacier* or an *Alpine glacier*, because first studied in the Alps.

Although the moving ice conforms to the bed over which it passes, it does not yield itself to the irregularities as easily as does water. When it passes through a narrows or over a steep and rough descent, it is broken into long,

deep cracks called *crevasses*. These make travel along glaciers sometimes very dangerous. The travelers are usually tied together with ropes, so that if one of the party slips into a crevasse, the others will be able to hold him up and pull him out.

A glacier, like a river, is found to flow fastest near the middle and on top, and slowest at the bottom and on the

Crevasses in a Glacier

Danger points in travel over glaciers.

sides. The rate of motion in the Alpine glaciers varies generally somewhere between 50 feet and one third of a mile in a year, being greatest in the summer and least in the winter.

Alpine glaciers are found not only, as the name would indicate, in the Alps, but also in Norway, in the Himalayas,

among the higher mountains in the western United States, and in fact wherever the snow accumulates in the mountain valleys year after year.

THE FIESCH GLACIER
A winding "river" of ice, bearing a medial moraine.

As glaciers creep down the valleys, dirt and rocks fall upon their edges from the upper valley sides and are borne along upon the ice. If two glaciers unite to form a larger one, the débris upon the two sides which come together forms a layer of dirt and rocks along the middle of the larger glacier. At the end of the glacier this material which it has borne along is deposited in irregular piles of rock and dirt.

The accumulations of débris along the sides are called *lateral moraines,* those in the middle, *medial moraines,* and those at the end, *terminal moraines.* Great bowlders may be carried along on the ice for long distances without the edges being

worn, since they are carried bodily and not rolled as in streams.

On the under surface of the glacier, rocks are dragged along firmly frozen into the ice. The weight of the glacier above presses them with tremendous force upon the surface over which the glacier passes. In this way scratches or grooves are made in the bed rock underlying the glacier, as well as upon the bowlders themselves. Scratches

A STONE SCRATCHED BY A GLACIER

of this kind are called *glacial scratches*. The rubbing of the rocks upon each other wears them away and grinds them into fine powder called *glacial flour*, which gives a milky color to the streams flowing from glaciers.

If a glacier extends over a region where the surface has been weathered into soil, this fine material may be shoved along under the ice for great distances.

Wherever glaciers are easily approached they form a great attraction for the summer tourist. The glistening white snow fields circled by the green foliage of the lower

slopes, with the glaciers descending in long, white arms down the valleys, pouring out turbulent, milky-colored streams from their lower ends, and here and there covered with bowlders and long, dark lines of medial moraines, form a picture which once seen is never forgotten, and the enticement of which lures the traveler again and again to revisit the fascinating scene. The exhilaration of a climb over the

THE DANA GLACIER IN THE HIGH SIERRAS

pathless ice with the bright summer sun shining upon it, the bracing air, and the ever-changing novelty of the surroundings make a summer among the glaciers almost like a visit to a land of enchantment.

For this reason Switzerland has become the summer playground of Europe and America. There the tourist crop is the best crop that the natives raise, and the scenery is more productive than the soil.

Norway, with the additional beauty of its fiords, is fast

becoming another Mecca of the tourist, and this region, denuded and made barren by the ancient glaciers, is now becoming rich and prosperous because of the glacial remnants still left. The high Sierras, too, are each year enticing greater

A View of the Jungfrau, Swiss Alps

Showing the snowy mountains and verdant valleys, which make Switzerland the delight of the tourist.

and greater numbers of travelers to enjoy their wonderful beauties and invigorating climate.

Greenland and the Antarctic Ice Fields. — The whole of the island of Greenland is covered with a deep sheet of ice except a narrow border along a portion of the coast and the part of the island north of 82°, which has little precipitation. The extent of the ice sheet is nearly equal to the combined area of the states of the United States east of the Mississippi and north of the Ohio. The depth of the

ice is not known, but probably in some places is at least several thousand feet. Although along the coast mountains rising from 5000 to 8000 feet are not uncommon, yet in the interior the thickness of the ice is so great that no peaks rise above it.

The surface of the inland ice is a smooth snow plain. Extending from this ice field are huge glaciers having at their ends a thickness of from 1000 to 2000 feet.

In the Antarctic region an area vastly greater than Greenland is covered with ice probably of a greater thickness. Although little is known about this ice cap, it is thought by some explorers to be nearly as large as Europe and to rest partly on an Antarctic continent and partly on the sea bottom.

AN ICEBERG

Icebergs. — When a glacier extends out into the sea, the water tends to float the ice. If it extends out into deep enough water, the buoyancy of the water will be sufficient to crack the ice, and the end of the glacier will float off as an iceberg. Glacial ice is about eight ninths under water when it floats.

Icebergs may float for long distances before they melt. In the North Atlantic the steamer routes are changed in the summer months for fear of running into floating bergs.

Some of the most appalling disasters of the sea have been due to ships colliding with icebergs.

Glacial Period. — Careful examination of all the surface formations over large areas of what are now the most thickly populated regions of North America and Europe has led geologists to believe that at a former period in the earth's history, perhaps not more than a few thousand years ago, the northern part of both continents was covered with a thick layer of ice. Evidences of this ancient ice covering are seen in North America as far south as the Ohio River and extending over a vast region which now enjoys a temperate climate. This mantle of ice after several advances and retreats finally disappeared, leaving the country as we now find it.

A Bowlder Borne along on Top of a Glacier

Notice the size as compared with the umbrella.

Although the border to which the ice extended and many of the changes which the ice made in the surface of the country have been carefully studied and mapped, yet the cause of this extension of the ice and the exact time at which it occurred have not yet been determined. Many theories have been brought forward to account for it, but none of them explains all the facts.

That the ice was here seems to be sure, but exactly when

or why is unknown. This period when the ice was of great extent is called the *Glacial Period.* Probably during the earth's history there have been several of these periods, but

AREA IN NORTH AMERICA COVERED BY THE ICE OF THE GLACIAL PERIOD

to the last is due the great change wrought upon the present surface of the country and upon plant and animal life.

The greatest ice invasion during this period extended from northern Canada across New England into the sea,

across the basins of the Great Lakes and the upper Mississippi valley and across a part of the Missouri valley. It wrapped in its icy mantle almost the entire region between the Ohio and Missouri rivers and the Atlantic Ocean.

Another great ice invasion spread out from the highlands of Scandinavia. As in later days the Norsemen, so at that time the glacial ice, overspread northern Europe, carrying Scandinavian bowlders across the Baltic and what is now the basin of the North Sea, forerunners of the Scandinavian sword which in later ages carried devastation to these regions.

Prehistoric man probably saw the great ice mantle; he may even have been driven from his hunting grounds by its slow encroachment. His rude stone implements are found mingled with the glacial gravels. But like the spreading ice he has left no record from which the time or cause of the Glacial Period can be determined.

The thickness of the ice over these central areas was very great, probably approaching a mile. The pressure on the ground below must have been tremendous and the scouring and erosive effect vast indeed. The soil which previously covered the surface was swept away and borne toward the ice margin, leaving the rocks smoothed and bare.

Glacial Formations. — The traces left by these ancient glaciers are unmistakable. When a glacier melts, all the material which it has moved along under it as well as that which it has carried on its surface or frozen in its mass is deposited, forming what is called ground moraine. This is the formation which constitutes the soil of many of our northern states. The soil throughout the glaciated region

is not of the same composition as that of the underlying rock; it must have been transported.

Sometimes the end of a glacier remains comparatively stationary over an area for a long time, owing to the fact that the advance of the ice is just about balanced by the melting. In this case the morainic material which has collected on the top of the glacier is deposited, forming irregular heaps of bowlders, gravel, and sand, with inclosed

Bowlders and Sand Left by a Retreating Glacier

hollows between. When the glacier has retreated, ponds and lakes are formed in the depressions, and streams wander about in the low places between the morainic heaps, receiving the overflow of some of the lakes and ponds. The arrangement of the streams is unsymmetrical and without order. The whole surface is a hodge-podge of glacially dumped material — a terminal moraine country. It was this sort of country that made the East Prussian campaign of the World War so difficult for both Russians and Germans, and rendered the final defeat of the Russians so disastrous.

A VALLEY IN NORWAY ROUNDED OUT BY GLACIERS

The moisture in the atmosphere in this region makes it necessary to hang the hay up to dry, as seen in this picture.

Where a glacier has little load, as near its source, the bed rock is stripped bare, smoothed, polished, and scratched by

the material which the ice has scraped over it and borne along. Here the soil that is left when the ice has retreated is very thin. Such is much of the country of New England and of eastern Canada.

The valleys through which glaciers have gone are left rounded out and shaped like a U.

MÄRJELEN LAKE

Glacial Lakes. — The advancing or retreating ice may happen to make a barrier to the escape of the drainage, and thus may form a lake with an ice dam at one end. The lake will continue to exist only so long as the ice obstructs the drainage. The Märjelen Lake in Switzerland is a well-known example of this.

Toward the close of the Glacial Period a vast lake of this kind was formed in the northern part of the United States.

It extended over the eastern part of North Dakota and about half of the province of Manitoba. The slope of the land is here toward the north. As the ice retreated northward it formed a barrier to the drainage and dammed back a great sheet of water in front of it. When the ice melted, the lake was drained, leaving the flat fertile plain through which the Red River of the North now flows. Glacial lake plains of this kind form fertile areas of great agricultural value. The North Dakota-Manitoba area is now one of the most productive wheat regions in the world.

Prairies of the United States. — North of the Ohio River and extending westward beyond the Mississippi is a region of rolling land with a deep, rich soil. Early in the last century it began to be rapidly populated on account of its great agricultural advantages. Owing partly to the fineness of the soil, but mostly to the frequent burning over of the region by the Indians, the area was destitute of trees except in some places along the river courses.

Thus the immigrant did not need to go to the trouble and delay of clearing the forests before beginning to farm. Cultivation could begin in earnest with the first spring, and, as a rule, rich harvests could be obtained. The soil here is transported soil; it is deep and unlike that of the underlying rock. In some places it is rather stony and in others very fine and without stones. It is so deep that the underlying local rock is seen only in deep cuts.

This soil was probably deposited by the great continental glaciers which once covered the region and was spread out either by the action of the slowly moving ice or by the water from the melting ice. This water flowed over the surface in shallow, débris-laden streams, bearing

their silt into the still waters of transient ice-dammed lakes. Whatever the original surface of the region, at present it is an irregularly filled plain due to the ancient ice sheet. As the soil is composed of pulverized rock not previously exhausted by vegetable growth, it is strong and

Alfalfa Cutting on the Fertile Prairies

enduring, so that this country has, since its settlement, been noted for its productivity.

Soils Produced by Decay. — All the agencies we have discussed and still others have contributed to breaking down the rocky crust of the earth into soil, thus preparing the way for plant life. The very plants themselves and the animal life which they support must die and return to the soil from which they came. If it were not for this the earth would eventually be encumbered with the dead forms of plants and animals; and the substances of which these bodies are composed would eventually be exhausted from the soil.

Thus even decay may be looked upon as a process friendly to man.

Decay is a very complex process. It is produced by forms of life so small that they can be seen only with a microscope. There is good reason to believe that there are forms so small that even the most powerful microscopes will not reveal them. The most important of these minute forms of life are called *bacteria*. They exist in uncountable millions almost everywhere. Scientists are acquainted with over 1500 different kinds of bacteria, and each kind has its own peculiar characteristics. Molds and yeasts are other low forms of life that help in the processes of breaking down, or disintegration.

All these minute forms of life must have considerable moisture and some of them, at least, must have free oxygen in order to thrive and to accomplish their work. Almost every one who has walked through the woods has noticed how much more rapidly damp wood decays than dry wood. It is to keep moisture and air from wood that we paint it, so that bacteria may not have in it living quarters favorable to their work of destruction.

Cycles of Change. — Sometimes areas where soils have accumulated for centuries and centuries have been gradually submerged below the waters of the sea. There these soils, and even undecayed plant growths, have been consolidated into sedimentary rocks. Ages afterward these areas have again emerged and the whole process of tearing down has begun anew. And so the cycles of building up and tearing down continue. Sun, water, ice, bacteria, the movements of the atmosphere, and the slow movements of the earth's crust are constantly working in league with one another to tear down what many of the same agencies have worked steadily to build up.

SUMMARY

The surface of the earth is constantly changing; in fact, change is the fundamental law of life. There are forces constantly building up, and other forces just as steadily tearing down. Among those forces which produce change are running water, with its power to erode and dissolve; freezing water, with its tremendous expansion; the moisture of the air; the gases of the atmosphere; heat; and the winds.

But the agent that has had most to do with preparing the soils of the great grain-bearing regions of the northern hemisphere is ice in the form of glaciers. Glaciers have their origin in upper latitudes or altitudes, where the snow accumulates from season to season and is gradually transformed by pressure into ice. This may spread out and creep down the valleys like slow flowing rivers. As glaciers creep down the valleys, the dirt and rocks fall upon their edges from the upper valley sides and are borne along upon the ice. These are called lateral moraines. If two glaciers unite to form a larger one, the débris upon the two sides which come together forms a layer of dirt and rocks which is called a medial moraine. The pressure of the glacier on its bed also wears away the rocks and pulverizes them into soil. When the end of a glacier melts, the débris that is deposited is known as a terminal moraine.

Almost the whole of the island of Greenland is covered with a deep sheet of ice. The depth of this ice sheet is not known, but probably in some places it is at least several thousand feet. In the antarctic region an area vastly greater than Greenland is covered with ice, probably of a greater thickness. When a glacier extends out into deep

water, especially in the sea, the buoyancy of the water is sufficient to crack the ice, and the end of the glacier floats off as an iceberg.

There are many evidences that large areas of what are now the most thickly populated regions of North America and Europe were once covered with thick layers of ice. This mantle of ice after several advances and retreats finally disappeared. The period of the last of these several advances of glacial ice to southerly latitudes is called the glacial period. These ancient glaciers have left unmistakable traces. They scoured out depressions in the earth, some of which now form small lakes and ponds. They pulverized the rocks in their course and transported the soil thus formed to latitudes where it now serves agricultural purposes. They changed the direction of flow of many rivers and dammed back great sheets of water into lakes which disappeared when the glaciers melted, leaving flat, fertile plains.

The very plants themselves and the animal life which they support must die and return by decay to the soil from which they came. Thus even decay must be looked upon as a soil-forming process which is friendly to man. Decay is produced by bacteria and other minute forms of life which must have considerable moisture in order to thrive and accomplish their work.

Sun, water, ice, bacteria, the movements of the atmosphere, and the slow movements of the earth's crust are constantly working in league with one another to tear down what many of the same agencies have worked steadily to build up.

Questions

What examples of rock weathering have you ever seen?
In what ways has wind acted as a soil builder?
In what ways has ice acted as a soil builder?

How are glaciers formed? How have they modified the surface of the region where they are found?

What was the extent of the North American ice sheet during the Glacial Period?

How has the Glacial Period affected the present agricultural and industrial conditions of the country over which the ice spread?

In what ways does the process of decay affect the soil?

CHAPTER XI

MAN'S USE AND CONSERVATION OF SOILS

Importance of the Soil. — The World War has awakened most people to the dignity and importance of tilling the soil. For once, it has been brought home to us that we are dependent upon the nation's farms for our very existence. From the soil, either directly or indirectly, come all the necessaries of life, our food, our clothing, and most of the building-materials and furnishings of our homes.

Soil. — **Experiment 88.** — Into a 16-oz. bottle nearly full of water put a small handful of sand, and into another bottle about the same amount of pulverized clay. Shake each bottle thoroughly and allow the water to settle. Which settles the more rapidly? Which would settle first if washed by a stream whose current was gradually checked?

Wherever the inclination is not too steep, we find the surface of the bed rocks covered for varying depths with *soil.* It is upon and in this that plants grow. In it lies the wealth of our agricultural communities. On examining this soil, it will be found that in some places it grows coarser and coarser the farther down we dig. The coarser the pieces become, the more they resemble the bed rock, until finally they pass by imperceptible stages into it. This kind of soil is called *local* or *sedentary soil.*

In other localities the coarseness of the soil does not materially change as we dig into it, but suddenly we come

upon the surface of the bed rock, which may contain few, if any, of the constituents which were in the soil. This soil, which in no way resembles the underlying rock, is called *transported* soil. We have already learned how most of it reached its present position.

LOCAL SOIL

This soil has been weathered from the underlying rock.

The first kind of soil has evidently been formed in some way from the rock below, since it gradually shades into this rock. This kind of soil changes with the change of the bed rock. A striking illustration occurs in Kentucky, where the rich and fertile "Blue Grass" region is bounded by the poor and sandy "Barrens." The one is underlaid by limestone and the other by sandstone.

The soil at the surface is usually finer than the soil a foot or so below the surface. Sometimes it has a great deal of decayed vegetable matter mixed with the decomposed rock and to this its fertility is often largely due. Some

soils are made up almost entirely of decayed vegetable matter, peat, and muck. The underlying coarser and lighter colored soil, which contains little if any vegetable matter, is usually called the *subsoil.*

Composition of Soils. — **Experiment 89.** — Examine under a strong magnifying glass samples of sand, loam, clay, peat, and other kinds of soil. Notice the different kinds of particles composing the different soils and the shapes of these particles.

Experiment 90. — Put a handful of ordinary loamy soil into a fruit jar nearly full of water and allow it to stand for a day or two, shaking occasionally. At the end of this time shake very thoroughly and after allowing it to settle for a minute, pour off the muddy water into another jar. Allow this to stand for about an hour and then pour off the roily water and evaporate it slowly, being careful not to burn the material left. Examine with the eye, by rubbing between the thumb and fingers, and with a magnifying glass, the three substances thus separated. These three separates will be composed largely of sand, silt, and clay.

FIGURE 93

If a compound microscope (Figure 93) is available, mix a bit of the silt and of the clay in drops of water and put these drops on glass slides. Examine the drops under the low power of the microscope. Notice the little black particles of decayed vegetable matter, also the little bunches of particles that may still cling together. Why was it necessary to soak the soil so long? Draw the shapes of a few of the particles. Describe the composition of the soil you have examined.

If we examine most soils with a microscope, we shall find that they are composed, as was seen in Experiment 90, of many different kinds of material. Some of these materials dissolve slowly in water and thus furnish food for plants; others are insoluble.

In different soils the particles vary greatly in size as well as in composition. In gravel the particles are large and in a gram's weight there would be but few; in sands

RELATIVE SIZES OF SOIL PARTICLES
From left to right: clay, silt, sand, gravel.

there are many more, dependent upon the fineness; in silt particles are still smaller; and in a gram of clay there are several billion particles. Agricultural soils, intermediate between sand and clay, are usually called *loams*. There are sandy loams and clayey loams, with many intermediate varieties. As the mineral part of the soil is derived entirely from the rocks, only those minerals which were present in the underlying rock can be present in sedentary soils, whereas in transported soils the underlying rock has had no influence upon the soil.

The minerals composing the soil must furnish certain

substances for the support of plant life. Many of these minerals are needed in such small quantities that most soils have an abundance of them. Nitrogen, phosphorus, and potassium are the soil elements that are used most freely by the growing plant.

Plants also require a great deal of water. Yet few plants thrive if they are submerged in it, or even if their roots are submerged. Air is also necessary to the growth of plants. Air must reach not only the part of the plant growing above ground but the underground portion as well.

But if a soil had all necessary substances for plant growth in it, it would still lack fertility if it were not for the microscopic life of the soil. Some germs increase the fertility of the soil and some decrease it. If those which increase fertility are to thrive, certain conditions must be maintained. It is the skill of the agriculturist in maintaining and increasing these favorable conditions which largely determines his success or failure.

Water Film on Soil Particles. — **Experiment 91.** — Take about a quart of soil from a few inches below the surface of the ground and after sifting out the large chunks, put it in a sheet iron pan and carefully weigh it to the fraction of a centigram. Place the pan containing the soil in a drying oven or ordinary oven, the temperature of which is but little above 100° C. The soil should be spread out as thin as possible. Allow it to remain in the oven for some time, until it is perfectly dry throughout. Weigh again. The loss of weight will be the weight of water contained in the soil. As there was no free water in the soil how was this water held? Dip your hand into water and notice how the water clings to it after it is withdrawn. Examine with the eye and the lens several particles of the original soil as taken from the ground and see if there is a water film on each of these as there was on the wet hand.

Experiment 92. — Take the soil that has been dried and weighed in the previous experiment and heat it throughout to a red heat

over a Bunsen burner or in a very hot oven. Weigh again. If there is still a loss of weight this must be due to the burning of the organic matter — rotten twigs, roots, leaves, etc. — which was in the soil. Soils differ greatly in the amount of water they contain and in the amount of organic substance present.

We have seen from Experiment 91 how the soil takes up water, and how each little particle has a film of water around it. Little hairs on the plant roots are prepared to take up these little films of water which surround the soil particles. These water films have probably dissolved a minute amount of material from the soil particles, and this material enters into the plant and can be used for food.

Experiment 93. — Compute the area of a cubical block of wood four inches on a side. Cut the block in two. Compute the combined area of the two pieces. Cut each of these two pieces in two. Compute the combined area of the four pieces. Cut each of the four pieces in two. Compute the combined area of the eight pieces. What effect does dividing the block into smaller and smaller pieces have upon the total surface area? Has the mass or volume of the wood been increased?

We found in Experiment 93 that the more we subdivided the block the greater was the combined area of the pieces. This makes clear an important difference between coarse and fine soils. The smaller the particles are in a given volume of soil, the greater is the total surface to be covered by film water. Then too, the smaller the particles, the more readily are they dissolved and the greater is the amount of food within reach of the root hairs of plants.

Soil air. — **Experiment 94**. — Fill an 8-oz. bottle with soil taken from a few inches below the surface. Fit the bottle with a two-holed rubber stopper having the long neck of a three or four-inch funnel pushed as far as possible through one hole and a bent de-

livery tube just passing through the other hole. See that there is no air space between the soil and the stopper. The soil in the bottle should be as hard packed as it was originally in the ground. If necessary, push a wire down through the neck of the funnel so as to free all hard-packed particles of soil in it.

Connect the delivery tube with a bottle full of water standing inverted on the shelf of a pneumatic trough. Pour water into the funnel until it is full, and keep it full during the rest of the experiment. Allow the apparatus thus arranged (Figure 94) to stand for some hours. Air will collect in the bottle over the pneumatic trough. Where did it come from? When the soil in the bottle has become entirely saturated with water, roughly compare the amount of air collected with the volume of the bottle containing the soil. What part of this soil's volume is the collected air?

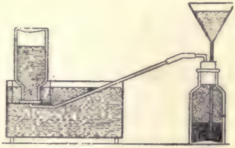


FIGURE 94

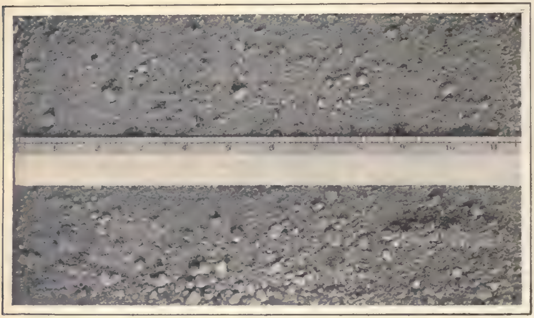
We have seen by this experiment that soil contains air as well as water. Air is needed if plants are to flourish; and it is necessary that soil air be changed frequently, just as it is necessary that air in living rooms be changed if people are to flourish. The soil must be ventilated. Plant roots must have air to breathe.

Fertile Soils. — Rock disintegration does not furnish all the complex materials needed for the growth of agricultural plants. Only the lower orders of plants, such as lichens, can grow on soil as at first formed.

A fertile soil is the product of ages of plant and animal life, labor, and decay. One of the most important plant-foods that is furnished by these means is nitrogen. It is an element that enters into the structure of every living thing. Practically all the nitrogen compounds in the earth's soil

have been put there either by the decay of plant and animal matter — organic matter — or by the direct efforts of certain kinds of bacteria.

Nitrogen is a gas that constitutes about four fifths of the atmosphere. Yet the higher forms of plant and animal life can no more use the free nitrogen of the atmosphere



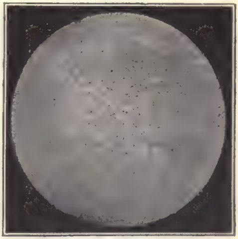
SOIL IN GOOD TILTH

than a human being can digest carbon. The nitrogen must be chemically united with other elements into compounds that are soluble in water before the plant can make use of it for food. Directly or indirectly, plants furnish the entire nitrogen supply of animals. Partially decayed organic matter in the soil is called *humus*.

We have learned that decay is caused by minute living things, *germs*, the most important of which are the numerous kinds of *bacteria*. The soil teems with this germ life. It has been estimated that there are fifty thousand germs of various kinds in a gram of fertile soil. Certain kinds of bacteria work the humus over and over, each

kind doing a different work, until the proper nitrogen compounds are formed. When these are dissolved in soil water, they are ready to be taken up for food by the plant.

The *bacteria of decay* do not add to the nitrogen of the soil; they simply work over the nitrogen compounds that they encounter. Without their activities, the growing plant would die for want of properly prepared food. In the course of decay, various acids and gases are formed. The acids help to decompose certain minerals into soluble forms that the plant can use.



Soil Bacteria

If the acids become too abundant, they make the soil "sour," thus preventing the growth of needful bacteria. Such soil can be readily "sweetened" by the addition of sufficient lime. It is very easy to test whether a soil is sour or not, by placing a piece of blue litmus paper in a hole in the ground a few inches deep, and allowing it to remain there for several hours. If the blue litmus paper turns red, the soil is sour. When lime, which is a base, is mixed with sour soil, it unites with the acids of the soil to form salts that are not injurious to the needed bacteria.

Soil Fertilizers. — So rapidly do the growing plants use up soluble compounds of nitrogen that the nitrogen would soon be removed from most soils if it were not in some way replaced. There are two other substances that are much needed by plants and that are soon exhausted from the soil

by the growing and harvesting of crops. These are phosphorus and potassium. Wheat crops, for example, rapidly exhaust soluble phosphorus compounds from the soil; and generous supplies of potassium compounds are necessary for the successful raising of cotton.

Substances that contain elements needed for the life and growth of plants are called *fertilizers*. The most common

SOUTHERN COTTON FIELD

fertilizers are manures. They contain nitrogen, potassium, and phosphorus, in about the proportions needed for the raising of ordinary crops.

Commercial fertilizers generally contain one or more of the three elements mentioned, in proportions adapted to the needs of varying crops. Saltpeter is a compound rich in nitrogen, and is therefore a good fertilizer. The most common way in which phosphorus is obtained for fertilizing is in the form of phosphoric acid. Much of this is prepared at stockyards from by-products, formerly wasted. Phos-

phate rocks, which are derived from the deposits of bones of prehistoric animals, are abundant in many places and furnish tons of phosphorus compounds for fertilizing.

Wood ashes enrich soil because they contain potash. Up to the beginning of the recent World War, the great potash beds of Germany supplied most of the potash used in agriculture. After the war started the United States began making efforts to locate potash beds and to produce potassium compounds in various ways.

In October, 1918, Secretary Lane of the United States Department of the Interior announced that within two years the United States would be independent of the German supply. Chemists have discovered practical processes by which to produce potash from the brine and from the deposits of old salt lakes in certain western states. They have also found ways of extracting potash from seaweeds, which have never before been of direct service to man; from minerals that have heretofore been considered worthless; from the fumes of smelters and from the dust of cement plants, which have hitherto been considered not only useless but even injurious. Thus chemistry turns waste into wealth.

Fertilizing Agents. — Among the most important fertilizing agents are the *nitrogen-fixing bacteria.* These differ from the other kinds of soil bacteria mentioned, in that they are able to take nitrogen directly from the soil air and to combine it into compounds. Farmers know that if a field is sowed to clover or to soy-beans, for example, it becomes more fertile. This is owing to the fact that the nitrogen-fixing bacteria live and multiply in great numbers in knots, or nodules, on the roots of these plants. When the clover

or bean crop is harvested, the roots are plowed under to enrich the soil.

Animals like moles and gophers plow their holes through the soil, mixing up the particles and making the soil porous, so that the water can readily get in to aid in breaking up and decomposing the soil particles. These holes also provide openings through which plant roots and soil organisms can obtain the oxygen and dissolved food they need. Ants each year move vast quantities of fine material to the surface, and in some places change the surface soil in a few years.

BACTERIAL NODULES ON BEAN ROOTS

Angleworms, the most important animal soil builders, channel the soil with their burrows, thus providing ready-made openings for the growing roots and by increasing the porosity of the soil aid in its ventilation and drainage. They swallow the soil as they make their burrows, in order to get the decaying vegetable matter for food, and they grind it fine as it passes through their bodies. Every year they bring to the surface great quan-

tities of this finely ground soil mixed with the undigested vegetable matter. Darwin estimated that the angleworms in English soil deposited one fifth of an inch of these castings each year over some parts of the surface. This is the finest kind of fertilizer. It is a common saying that the more angleworms the better the soil.

ANTHILL

This soil has been brought from below and piled up by the ants.

Agricultural Soils. — As has already been shown, soils differ greatly in fineness, mineral composition, and waterholding capacity. They also differ greatly in the amount of decayed vegetable material or *humus* in them. The humus is a most important soil ingredient. It not only furnishes plant food, but it also increases the capacity of the soil for holding moisture and prevents the soil particles from packing together too closely.

MOLEHILLS

Showing how these animals burrow up the soil and make it porous.

In sandy soils, since there is usually little humus, the water soon drains out and plants become parched. Such soils

warm up quickly in the spring and dry out rapidly after long wet spells. When humus and plant food in the form of manure are added, these soils are especially adapted for growing early crops and crops that do not require a great deal of moisture, such as grapes. The "Fresno Sand" of California and the sandy coast plains of the eastern United States are soils of this kind.

LUMPY SOIL

The result of cultivating at the wrong time.

In clay soil the particles are extremely small, as are also the spaces between the particles. Water is therefore taken up very slowly. It is, however, held tenaciously. Because so much heat is absorbed in raising the temperature of the soil water and in evaporating the water that slowly rises to the surface, clay soils are cold.

When clays become wet, they are very sticky and cannot be worked. When they dry, they become very hard and crack. If cultivated at the wrong time they break into hard lumps and render further cultivation difficult. The

adobe soil of the West is of this character. If the soil is nearly pure clay, it is useless for farming. If sufficient sand or humus can be added, clay soils become valuable, since they usually contain the elements needed by plants.

A soil having grains about midway in size between sand and clay is called a *silt*. This is usually a most fertile soil. It is the soil of the western prairies and the great grain-producing states of our country. It holds water well, contains an abundance of plant food, and is easily cultivated. Between these three types — sand, silt, and clay — there are all grades of soils, presenting problems of various degrees. The problem of the farmer, however, is to maintain a soil which holds water but is well drained, which contains the elements plants need, and which is mellow enough to be well aired and to let the plant roots grow.

ADOBE SOIL

A heavy clay soil, very fertile but hard to cultivate.

Soil Water. — Although many soils contain everything needful for the production of agricultural plants, yet the

MUD CRACKS
Showing the way clay cracks when it dries.

rainfall is insufficient or so unevenly distributed that these plants are unable to grow. This is true over a large area of the United States, and the same conditions often prevail over the usually well-watered part of the country in times of drought. The question of increasing the water-holding capacity and of preventing the loss of water by evaporation or in other ways is a very important one.

PRAIRIE SCENE
Showing modern methods of harvesting the crop from fertile silt soil.

Experiment 95. — Weigh out equal amounts (about 100 g. each) of dried gravel, coarse sand, and very fine sand. Put each of these into a four-inch funnel which has been fitted with a filter paper. Pour water upon each until all that can be absorbed has been absorbed. Allow each to stand until water ceases to drop from the funnel. Weigh again, balancing the weight of the wet filter paper retainer by a similar wet filter paper placed on the weight side of the scales. Which of these substances is capable of holding the most water? Since water does not penetrate into the grains composing these different substances the difference in water-holding capacity must be due to the different sizes of the grains.

ALFALFA PLANT
The alfalfa roots go deep to seek water.

If we dig deep enough into almost any soil we shall find water. Wells show this. Certain trees and plants have such long roots that they can reach the underlying water and flourish where other plants will die. When wet lands are so drained by tiling that the plants can send their long roots down to this constant water supply or *water table*, as it is called, they stand a drought

much better than plants grown on undrained land where the water table has not so uniform a depth. The too frequent surface watering of plants is bad for them, as it keeps

RICE SWAMP
A valuable plant growing in water.

their roots so near the surface that the plants are unable to withstand slight drought.

Certain kinds of plants need more water than others. Water lilies, reeds, rice, and other plants grow with their roots submerged in water. Other plants, such as the cactus,

sagebrush, and mesquite, can grow only where the supply of moisture is very scant. Most cultivated crops cannot live in a soil that holds too much free water; that is, water that lies between the particles of the soil instead of in a film around them. Too much free water excludes the air from the ground and the plant literally drowns. Even where there is not sufficient free water to drown the plant, insufficient under-drainage keeps the soil cold and prevents the injurious substances in solution from being washed out of the soil. This explains why flowerpots always have a drainage-hole and why farmers are sometimes compelled to tile their farms.

FIGURE 95

Experiment 96. — Place small glass tubes of several different bores in a dish of colored water. In which is the surface of the water higher, in the tubes or in the dish? In which tubes is it the higher, those of large or small bore?

Experiment 97. — Place two wide-mouth 4-oz. bottles side by side and fill one partly full of water. Put a coarse piece of cloth, or better, a lamp wick, into the water bottle and allow the other end to hang over into the empty bottle. (Figure 95.) Allow the bottles to stand thus for an hour. What happens? The force that causes the rising of water up tubes and wicks is called *capillarity.*

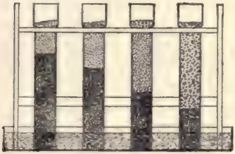
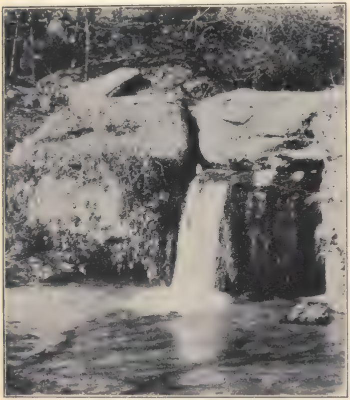


FIGURE 96

Experiment 98. — Tie pieces of cloth over the ends of four lamp chimneys. Fill one of the chimneys with coarse sand, another with fine sand, another with clay, and the fourth with a deep black loam. Stand each chimney in a shallow pan of water. (Figure 96.) Allow them to remain for a week, keeping water in the pan all the time. Note how high the water has risen in the different chimneys at the end of an hour; two days; a week.

It was found in Experiment 91 that each little particle of soil was surrounded by a film of water, even though there was apparently no water in the soil. This film will be replaced, if removed, just as the water in the top of the wick (Experiment 97) was replaced by water flowing up the wick. Roots get a large part of their water by absorbing the water films of the soil particles.



A Natural Spring

Coming to the surface between rock layers.

Gravity is continually pulling the soil water deeper and deeper into the ground. This deep soil water is frequently diverted to lower ground by impervious layers of soil or rock and comes to the surface as springs, or it may come gradually to the surface over a broad area a long distance away from where it fell and make a region, otherwise barren, fertile by subirrigating it.

Although land must be properly drained, the loss of water by drainage may in some cases be too rapid. It is often very essential to stop as far as possible downward passage of water, or *seepage,* as it is called. The water in seeping through the soil dissolves plant food and if allowed to drain off would decrease the fertility of the soil. Whatever de-

creases the porosity of the soil will decrease the seepage and thus help to retain the plant food. This may be done by adding humus, and sometimes, where the soil is very porous, by rolling. At the time rain is likely to fall, however, the soil must be kept loose and mellow so that the water can sink into it.

Evaporation is, however, the cause of soil's losing the greatest amount of water. Soil water is constantly mov-

AN ARTESIAN SPRING

A deep water layer has been pierced and the water diverted to the surface.

ing toward the surface on account of capillary action, and is being evaporated. This loss by evaporation must be counteracted, if in arid countries or during dry spells agricultural plants are to be provided with sufficient moisture.

Experiment 99. — Fill full of soil four tin cans having small holes punched in the sides and bottom. Water each with the same amount of water. Cover the first with about an inch of grass and the second with about an inch of sawdust, and weigh carefully. Weigh the third and fourth. Record the weight of each. Thoroughly stir the surface of the third, as soon as it is dry enough, about an inch deep. Keep this stirred. Let the fourth stand undisturbed. Weigh all four every school day for two weeks.

Keep a record of the loss of weight of each. Why have they lost weight? How do the grass, the sawdust, and stirring of the earth affect the loss? Suggest ways to keep soils from losing their moisture.

In Experiment 99, it was seen that if a layer of grass or sawdust was put on the top of the soil, the moisture did

DRY FARMING IN EGYPT

not evaporate so rapidly as it did when the soil was not covered. The grass could have been replaced by shavings, manure, or any substance which would protect the ground from the sun and wind. Protections of this kind are called *mulches*. They are most frequently used around trees, vines, and shrubs. It is impracticable to use them extensively on growing crops.

It was also found that soil water was not readily evaporated where the top of the soil was kept stirred, so that

the little capillary tubes by which the soil water reaches the surface were broken and the sunshine and air were kept from the under part of the soil by a layer of finely divided soil mulch. When the surface of the soil is thoroughly stirred or cultivated the particles are separated so far apart that the water cannot pass from one grain to another, and so is retained in the under layer ready for the plant roots. Thorough tillage of agricultural crops is perhaps the best way to assure the plants sufficient moisture in regions subject to droughts.

KAFFIR CORN
A plant suitable for dry farming.

In some parts of the arid region of the United States *dry farming* is practiced. The soil is deeply plowed and the plow often followed by a bevel wheel roller called a *soil packer*, in order to pack the under soil or subsoil so that the air cannot circulate through it and dry out the upper soil. The surface soil is then most thoroughly cultivated so as to make as perfect a soil mulch as possible. Thus, whatever moisture falls is kept from seeping below the reach of the plant roots and from evaporating from the surface.

In this kind of farming the aim is to use more than one year's moisture in growing a crop.

Crops are usually planted only every other year, two years' moisture being retained for one crop. The soil is, however, kept thoroughly cultivated all the time. Of course plants requiring the least amount of moisture are best adapted to dry farming.

IRRIGATION IN SQUARES

Irrigation is the most efficient means of raising crops in regions of insufficient rainfall or of droughts. Water is brought to the land from distant sources, or from flowing artesian wells, or is pumped from wells which have been sunk to an available water table. In this way water can be supplied to plants whenever needed. Where the ground is quite level it is often flooded, sometimes in larger or smaller squares, with little ridges separating the squares. A great deal of water is lost in this way by evaporation.

Another way is to plow furrows eight to ten inches deep in the direction of the surface slope and run the water into these from the irrigation ditch. In either case the water is allowed to soak in until the soil is thoroughly wet. The surface is then cultivated so as to check surface evaporation. It has been found that if the soil in certain irrigation regions

IRRIGATION IN FURROWS

does not have adequate under-drainage, it will become water-logged. Injurious substances from the soil that should be carried away by downward seepage and drainage are dissolved, carried to the surface, and left there by evaporation. In such cases, artificial under-drainage has proved a necessity.

In the last few years the government and many private

companies have spent millions of dollars in putting in irrigation plants. By this means thousands of acres of land which would otherwise have been valueless for agriculture have been made exceedingly productive.

Alkali Soils. — In dry regions where the rainfall all sinks into the ground and after remaining for a time rises to the surface and is evaporated, large areas are found upon which almost nothing can be made to grow even

Alkali Soil

Few plants can grow here because of the excess of alkaline salts.

when sufficient water is provided. Often in the dry season white or brown crusts appear scattered over the surface in large patches. The white crust usually tastes like Epsom salts and the brown like sal soda. The salts forming these patches have been dissolved out of the soil by the soil water and left on the surface when it evaporated.

Such substances are not found in wet regions because they are carried away by the water which runs into the streams. About the only way soil of this kind can be treated to make it productive is to irrigate and drain it, thus washing the salts out of the soil. This is just what is done by nature

in well-watered regions. Sometimes if there is not much alkali, deep plowing or the planting and removal of certain plants such as sugar beets, which are capable of growing in such soils, will sweeten it.

RECLAIMING ALKALI SOIL IN THE SAHARA

Soil and Man. — Although nature through countless ages has been preparing the soil, and generation after generation of plants and animals has been contributing to its

ROMAN PLOWING

Showing primitive methods.

fertility, yet it will not continue profitably to produce agricultural crops unless carefully handled by man. The materials taken from it must be replaced by fertilizers. It must also be thoroughly tilled in order (1) to keep in the moisture, (2) to prepare a mellow place where the roots of the plants may spread, (3) to provide air and water and

LABOR-SAVING MACHINERY

Two men with a tractor operate two binders and two shockers. The shocker is a new invention which receives the bundles of wheat, automatically assembles from 8 to 11 of them into a shock, and deposits the shock right side up. Each shocker saves the labor of at least two men.

humus needed by the bacteria which build up the soluble nitrogen compounds, and (4) to kill the weeds which would use the space and plant foods needed by the growing crops and would choke them out. Proper tillage probably has more to do with thrifty and productive farming than any other one thing. By careful tillage much expense for fertilizers can be saved and the value of the crop produced greatly increased.

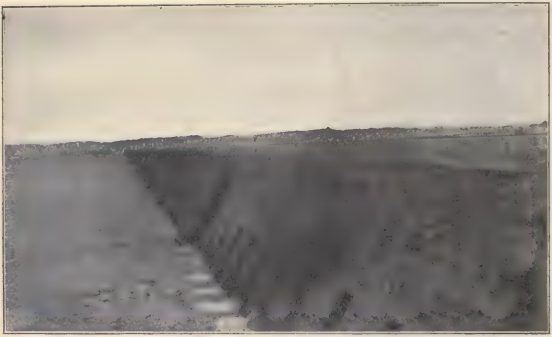
Value of Soils. — Many different factors enter into the determination of the value of a soil. Soils which in one locality would be of great value are almost valueless in other localities. Light sandy soil far from a market, unless transportation facilities are exceptionally good, is almost worthless, while the same soil near a city where

GOOD SOIL, A TRUCK FARM

fertilizers can be easily procured and where early vegetables find a ready market is of great value.

Different soils are adapted to different crops, and where a soil, although not good for many crops, is adapted for raising a crop which in its locality is valuable, the soil is called good. Thus the soil in many parts of Florida, although unsuited for raising most crops, is suited for orange trees and early vegetables, and so is a good soil. The stony soil in certain of the orange regions of California would be an exceedingly poor soil for most crops, but it is good for oranges and therefore it is most valuable.

Reclamation of Arid Lands and Low Lands. — Four thousand years ago the Assyrians made a veritable garden of the Tigris and Euphrates valleys by dredging lakes for the conservation of river flood waters and canals for distribution. Tanks, reservoirs, and irrigation canals were in existence in India centuries before Christ. There are evidences



East End of the Assuan Dam across the Nile

The greatest irrigation dam in the world.

that a prehistoric race had extensive irrigation works centuries ago in New Mexico and Arizona.

Modern methods of irrigation make it possible to reclaim large tracts of land that must have remained waste lands in ancient days. The building of great dams, the construction of permanent ditches, and even the boring of water courses through the sides of great mountains, are among the great tasks performed by the United States Government and by private companies in reclaiming large areas of land in arid sections of the West.

Results of a Sudden Flood

Soil and even buildings have been swept away.

A Cypress Swamp in Louisiana before Drainage

A floating dredge is used to cut a canal around the area to be reclaimed. The earth excavated from the canal is piled into an embankment inclosing the tract. In this tract a network of drainage canals and ditches is dredged from which the surface water is pumped out.

But there are other sections where by another sort of work millions of acres of exceptionally fertile soil may be reclaimed. Rich flood plains must be protected against periodic overflows that often ruin crops and sometimes ruin even the soil itself. The building of systems of levees

CYPRESS SWAMP RECLAIMED

This is the same section that was shown in the preceding illustration, after the land had been drained, cleared, and staked out for cultivation.

would prevent this, and the establishment of flood basins to catch the overflows from the rivers would furnish farmers in these sections with water for irrigation during the dry months that often succeed floods. The United States may well profit by the examples of ancient peoples in reclaiming such lowlands. Undrained areas of the Great Lakes region and of the coastal plains may also be reclaimed, as Holland

and Belgium have reclaimed so much of the surface of those fertile countries.

Forestry. — When rain drops upon the foliage of trees, its force is broken and it falls to the ground in fine spray. If the ground beneath is carpeted with leaves and humus, the soil is further protected from erosion. The water readily

BAD LANDS OF DAKOTA

Running water has so dissected this land as to render it valueless.

soaks into the soil made spongy by leaves and roots. When the rain is over, evaporation does not take place rapidly because of the double protection afforded by the shade of the trees and by the leafy carpet. If the trees are cut away the rain splashes down on the unprotected soil. Most of the water runs off the surface, often carrying fertile soil with it. Even the water which soaks into the ground is usually quickly evaporated from the unshaded surface.

In North America before the coming of the white man, there were probably extensive areas where the growth of forests had been checked by fires set by the Indians. The prairie regions were probably much enlarged by the annual grass fires. All this was done in order to make hunting less difficult. It is believed that the Bad Lands of Dakota were once a fertile region which the destruction of the forests

BAD FORESTRY

The hillside was stripped, leaving it a prey to erosion.

left a prey to running water. Erosion has left these lands valueless for agriculture. It is exceedingly difficult even to travel over them. It was in these natural fastnesses that the Sioux Indians made their last ineffective stand against the white man's civilization. But the white man has outdone the Indian in reckless destruction of the forests.

If a region is well supplied with forests so that the rain as it falls is held by the moss, leaves, and roots and pro-

tected from evaporation by the foliage, soil water will continue to be supplied to the surrounding open land long after it would have become dry had the forests been removed. Mountain soils have been found which hold back five times their own weight of water.

Slopes from which the forests have been removed become an easy prey to the forces of erosion, and the soil which

BAD FORESTRY

The forest was razed, leaving no small trees for future growth.

for thousands of years has been accumulating may be swept away by the rainfall of a few seasons, leaving the slopes bare of soil and devoid of vegetable life. Thus the sites of valuable forests, which by proper care might have been continual wealth producers, are rendered nearly profitless deserts.

The harmfulness, however, does not stop here. The rain that falls upon these slopes, and which was formerly retained by the roots and vegetation, so that it slowly

crept downward into the valleys and streams, now runs off quickly, flooding the rivers and doing damage to regions at a distance. Streams which formerly varied but little in their volume during the entire year now become subject to great extremes of high and low water. This renders them less useful for manufacturing, commerce, and water

BAD FORESTRY

The débris was left to feed the forest fires and all the standing timber was ruined.

supply, to say nothing of the frightful damage done each year by floods.

Not only is the destruction of our forests a menace to agriculture and to river navigation, but it actually threatens our future lumber supply. The ruthless destruction of vast forests in Europe during the World War has made more imperative than ever the conservation of what forests we have left in America.

In recent years the demand for lumber and wood pulp and the careless and wasteful way in which the forests have been handled by the lumbermen has greatly reduced

the forests of the United States. It has been authoritatively stated that if the present waste of our forest land continues, the timber supply of the country will be exhausted before 1940. Not only are the forests being recklessly cut down, but forest fires are each year destroying millions of dollars' worth of timber. When the importance of lumber to all kinds of industries is considered,

GOOD FORESTRY

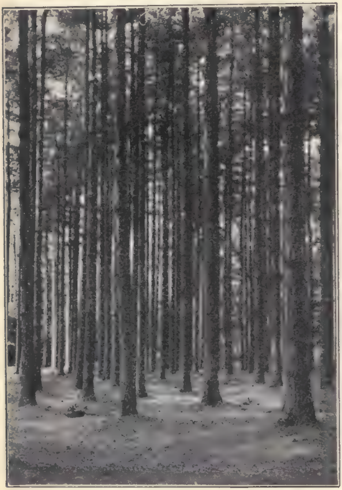
Notice how the underbrush and small timber has been cleaned up.

the rapid exhausting of our forest supplies becomes almost appalling.

When the native forests are destroyed, trees of other kinds may in time replace those removed, but frequently these are of less commercial value. Thus, when the conifer forests of the northern states are cut off, birches and poplars replace them. If only the larger trees had been cut, leaving the smaller and younger trees to hold the

ground, the more valuable forests might have been retained.

The destruction of the forests tends also to exterminate the wild animals and deprives man of a chance to get away from his artificial surroundings and obtain a knowledge and an enjoyment of life and nature which has been unaffected by his own dominant influence.



GOOD FORESTRY

Notice how carefully the underbrush has been removed to guard against fire.

In many European countries the forests have become a national care and not only is the cutting of trees, except under certain restrictions, prohibited, but the greatest care is maintained to guard against fires. In our own country the government has recently established a number of forest preserves which are carefully patrolled, and here the destruction from forest fires is rigidly guarded against. Great care of all forests should be taken by hunters, campers, and all others who visit them, and also by the railways passing through them. Loggers and lumbermen should see that it is to their

interest to maintain growing forests and not wantonly to destroy them.

SUMMARY

The soils which have been produced in one way or another, as described in Chapter X, are classified as local or sedentary soil, which is formed from the rocks directly beneath it; and transported soil, which is generally brought from other localities and deposited by water, ice, or wind. Soils are also classified according to the size of their particles, as gravel, sand, silt, and clay. The best agricultural soils are generally of the consistency of silt, and are called loams.

Nitrogen, phosphorus, and potassium are the soil elements that are used most freely by the growing plant, but these elements must be in chemical compounds with other substances before they are available as plant food. Plants also require air and water, and are dependent on the activities of soil bacteria. These bacteria cause such changes in organic matter of the soil that it may be used by the plant as food. Partially decayed organic matter in the soil is called humus. Humus is not only a source of plant food, but also serves to mellow the soil and to conserve soil water.

The most common fertilizers are manures. They contain nitrogen, potassium, and phosphorus in about the proportions needed for ordinary crops. Commercial fertilizers contain one or more of the elements mentioned, in varying proportions. The United States is now developing its supplies of commercial fertilizers and bids fair to be independent of foreign supplies. The most common fertilizing agents are the nitrogen-fixing bacteria, moles, gophers, and angleworms.

Some plants grow with their roots submerged in water, while others can grow only where the moisture supply is

scant. But most cultivated crops cannot live in a soil that holds too much free water. Land must, therefore, be properly drained. If, on the other hand, drainage is too free, it may wash the plant food out of the soil. Much more moisture is lost by evaporation than by under-drainage or seepage. In dry climates or during droughts, therefore, mulches and frequent stirring of the top-soil must be resorted to in order to conserve moisture.

Great areas in dry climates are frequently reclaimed by irrigation, while swampy lands are rendered useful by drainage. In the conservation of soils, nothing is more important than wise forestry. Forests retard evaporation of soil water, increase the underground supplies of water, and tend to prevent great extremes of high and low water in our rivers. The ruthless destruction of our forests also threatens our future lumber supply. Our own government has been taking steps in recent years to care for our forests scientifically. It deserves the coöperation in this of every good citizen.

Questions

Is the soil in your neighborhood local or transported? Does its character vary much in different places? Does its fertility vary? Are the soil particles large or small?

What would you suggest as the cause of any soil variations found in your neighborhood?

What conditions are necessary to produce a fertile soil?

What are the best farmers doing to increase the fertility of their soils?

How can the right amount of soil water usually be maintained?

What steps should be taken to guard our forests?

CHAPTER XII

THE SUN'S GIFT OF LIGHT

Light. — The sun is not only the source of almost all the heat of the earth but also of its light. We have developed artificial self-luminous bodies such as candles, lamps, electric lights, but none of these compares with the light given by the sun. The stars also furnish a little light.

Light is just as essential to life as heat is. If plants or animals are where light is entirely excluded, they begin to sicken and die. If they are placed where it is very cold, they freeze and die. Although the sun gives both heat and light, yet these two are not inseparable. We feel the heat given out by boiling water but there is no light, and we see the light of the moon but there is no appreciable heat. We usually say that we feel heat but cannot see it and see light but cannot feel it.

Direction of Light Movement. — **Experiment 100.** — Point the pinhole end of a camera obscura or pinhole camera (this consists of two telescoping boxes, the larger having a pinhole at the end and the smaller a ground glass plate (Figure 97)) at some object and move the ground glass plate back and forth until a sharp image of the object is formed. Sketch on a piece of paper the object and the image, showing the direction in which you think the rays of light must have traveled through the pinhole to form the image.

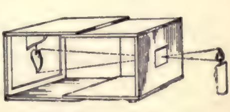


FIGURE 97

A photographic camera is constructed in the same way as this little camera, only a lens is placed behind the pinhole to intensify the image, and it is possible to exchange the ground glass plate for a photographic plate.


A Lake Mirror

There are certain properties of light which seem readily apparent from our daily experiences. We cannot see objects in the dark, but if a light is brought into the room so that it can shine upon them, they become visible. We see them because the light is reflected to us from them. All objects except self-luminous bodies are seen by reflected light. Most of the bodies that we know are dark and non-luminous. Sometimes some of these which have polished surfaces reflect the light from a luminous body and thus appear themselves to be furnishing light.

An example of this is often seen about sundown when the sunlight is reflected from the windows of a house, making them look as if there were a source of light behind them.

Any dark body whose surface reflects light appears itself to be luminous as long as the source of light remains, but grows dark again when the source is removed. This is the case of the moon. At new moon, the moon is so situated with respect to the sun that light is not reflected to the earth and we cannot see it. At full moon, half of the moon's entire surface reflects the sunlight, and it appears very bright.

If a candle is held in front of a mirror and we look into the mirror, we see the candle behind it. We know that the candle is not there but that its light is reflected by the mirror in such a way as to make it appear to come from behind the mirror. We see the candle by the light the mirror reflects.

If we wish to see whether the edge of a board is straight, we sight along it. If we wish to hit an object with a bullet, we bring the rifle barrel into our line of sight. We therefore feel confident that if light is traveling through a uniform medium, such as air usually is, it goes in a straight line.

The Intensity of Light. — **Experiment 101.** — Take two square pieces of paraffin about an inch thick, or better two squares of parowax, and place back to back with a piece of cardboard or tinfoil between them. When a light is placed on either side of this apparatus the wax toward the light will be illuminated, but not that on the other side of the cardboard. (Figure 98.)

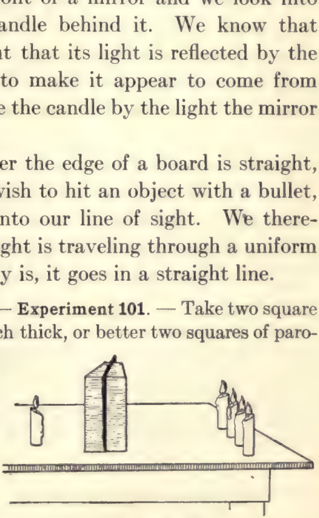


FIGURE 98

If lights are placed on each side, it is easy to see when both pieces of wax are equally illuminated, or receive the same amount of light. In this way the strengths of lights can be compared.

Place a candle about 25 cm. in front of one side of this apparatus,

and 4 candles, placed close together on a piece of cardboard so that they can be readily moved, about 90 cm. away on the other side. Move these candles back and forth till a position is found where both pieces of wax are illuminated alike. Measure the distance of the four candles from the wax. How many times as far away are they as the one candle?

The brightness of the sun's light is so great that even an arc light placed in direct sunlight appears as a dark spot. So great, however, is the sun's distance that the earth receives only a minute portion, less than one two-billionth, of the light and heat it gives out.

The standard measure for intensities of light is the candle power. This is the light given out by a standard candle,

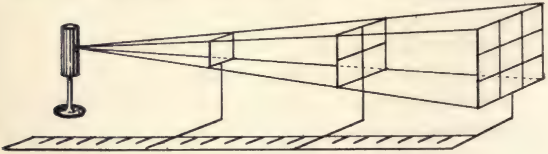


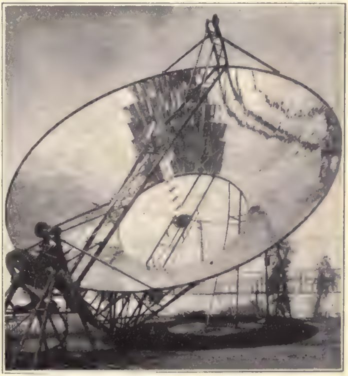
FIGURE 99

which is practically our ordinary No. 12 paraffin candle. The ordinary incandescent electric light is sixteen candle power. No comprehensible figures will express the intensity of the sun, using the candle power as a measure.

The intensity of light, like that of heat and electricity, and all forms of energy which spread out uniformly from their point of origin, varies inversely as the square of the distance from the source. This rapid decrease in the brightness of light as the distance increases is the reason why so small a change in the distance of a lamp makes so great a difference in the ease with which we can read a book. If we make the distance to the lamp half as great, we increase

the amount of light on the book four times; if one third as great, nine times. (Figure 99.)

Reflection of Heat and Light. — **Experiment 102.** — In a darkened room reflect by means of a mirror a beam of light from a small hole in the curtain, or from some artificial source of light, on to a plane mirror lying flat upon a table. If there is not sufficient dust in the air to make the paths of the rays apparent, strike two blackboard erasers together near the mirror. Hold a pencil vertical to the mirror at the point where the rays strike it. Compare with each other the angle formed by each ray with the pencil. Raise the edge of the mirror, and notice the effect on the reflected ray. Place the pencil at right angles to this new position of the mirror, and compare the angles in each case. How do the sizes of the angles on either side of the pencil compare?



A REFLECTION ENGINE

This engine uses the rays of the sun instead of coal in heating its boiler.

It has already been stated that the moon shines by reflected light. It is a matter of common observation that objects on the earth reflect both heat and light. In the summer, the walls of the houses and the pavements of the streets sometimes reflect the heat to such an extent that it becomes almost unbearable. In countries where the sun shines brightly nearly all of the time, as in the Desert of Sahara, reflectors have been so arranged as

to reflect the heat of the sun on to boilers to run steam engines.

The smooth surfaces of houses often reflect so much of the light falling upon them that the glare is thrown into the windows of surrounding houses into which the sun itself cannot shine. If one stands in the right position, the reflection of trees and other objects can be seen in a smooth lake. But the reflection cannot be seen if the position of the spectator is much changed. The reflected ray must therefore maintain a certain relation to the ray that strikes the surface from the object.

In Experiment 102, when the pencil was held perpendicular to the mirror at the point where the rays touched the mirror, it was seen that both the ray from the window and the reflected ray made about the same angle with it. These two angles are respectively called the *angle of incidence* and the *angle of reflection.* By most careful experimentation it has been found that the angles between each of these two rays, and the line drawn perpendicularly to the reflecting surface are always equal, or in other words *the angle of reflection is always equal to the angle of incidence.* (Figure 100.) This explains why, if you are standing in a room at one side of a mirror, you can see in the mirror only the opposite side of the room. We are accustomed to a similar law of reflection when we bounce a ball on the floor for some one on the opposite side of the room to catch.

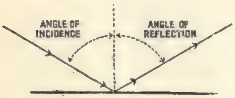


FIGURE 100

The Speed of Light. — In the latter part of the seventeenth century a Danish astronomer by the name of Roemer,

after carefully watching the brightest of Jupiter's satellites or moons as it revolved around the planet, noticed that the time of occurrence of its eclipses or passages behind the planet showed a peculiar variation. He accurately determined the interval between two eclipses or the time it took for a complete revolution of the satellite around the planet.

Using this interval he computed the time at which other eclipses should take place and found that as the earth in its revolution around the sun moved away from Jupiter the eclipses appeared to take place more and more behind time. Determining the exact time at which an eclipse took place when the earth was nearest to Jupiter, and computing the time an eclipse should take place six months later when the earth was farthest from Jupiter, he found that the actual time of the eclipse was 22 minutes behind the computed time. This slowness he said must be due to the time required by the light in crossing the earth's orbit. (Figure 101.)

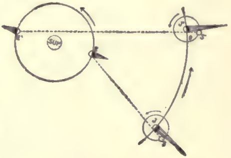


FIGURE 101

Many determinations of this kind have been made since those of Roemer, and it has been found that he was somewhat in error, as the time required by light in traveling across the earth's orbit is about 16 minutes and 40 seconds, or 1000 seconds. Since the diameter of the earth's orbit is about 186,000,000 miles the speed of light must be about 186,000 miles per second. Determinations of the speed of light have been made in several other ways with almost like results.

Refraction of Light. — **Experiment 103.** — Place a penny in the center of a five-pint tin pan resting on a table. Stand just far

enough away so that the farther edge of the penny can be seen over the edge of the pan. Have some one slowly fill the pan with water. How is the visibility of the penny affected? (Figure 102.)

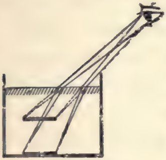


FIGURE 102

Experiment 104. — Fill a tall jar about two thirds full of water. Place a glass rod or stick in the jar. Does the rod appear straight? Pour two or three inches of kerosene on the top of the water. What effect does this have on the appearance of the rod?

Experiment 105. — Hold an ordinary spectacle lens such as is used by an elderly person, or any convex lens, between the sun and a piece of paper. Vary the distances of the lens from the paper. The heat and light rays from the sun are bent so that they converge to a point. Try the same experiment with a lens used by a short-sighted person, or a concave lens. This lens does not have the same effect as the convex lens. The rays are made to diverge. Why cannot long-sighted and short-sighted persons use the same glasses?

In the experiment of the penny in the dish, the water in some way bent the ray of light and made the penny come into the line of sight when it could not be seen before the water was there. The penny was apparently lifted up. This illustrates why ponds and streams look shallower than they really are. This experiment shows that when light is passing from one medium to another it does not always travel in the same straight line. Certain media offer more resistance to the passage of light than others and are called *denser* media. It is this difference of resistance which causes the bending of the ray.

Suppose that a column of soldiers marching in company front are passing though a corn field and come obliquely upon a smooth open field. (Figure 103.) The men as they come on to the open field are unencumbered by the corn-

stalks and will move faster, and thus the line of march will swing in toward the edge of the corn field. It can easily be seen that the bending of the line would be in the opposite direction if the soldiers were marching from the smooth field into the corn field. If the company front were parallel to the edge of the corn field, then the men would reach the open field at the same time and there would be no swinging of the line.

FIGURE 103

The above illustration roughly explains what happens when light passes from one medium to another. *Refraction* is the name given to this bending of light in passing through different media or through a medium of changing density. Twilight, mirage, the flattening of the sun's disk at the horizon, and other appearances, we shall find later, are due to this property of light.

Lenses. — The bending of light in passing from one medium to another has been turned to great advantage in the use of lenses. In the making of lenses, transparent substances are so shaped that when the rays of light strike them, they are bent into any desired direction. Experiment 105 shows that the rays may be brought nearer together (converged or focused) or spread farther apart (diverged). If the illustration of the line of march of the soldiers is kept in mind, it will be seen that the rays must always

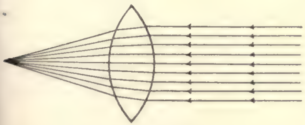


FIGURE 104

be bent toward the thicker part of the lens. (See Figures 104 and 105.)

If in Experiment 100 a convex lens is placed behind the small hole, the rays of light from a large area will be focused on the ground glass. If the plate is adjusted to the right position, a small, distinct picture will be formed. If a plate covered with chemicals that undergo change when exposed to light replaces the ground glass, a copy of the picture is left upon the plate. When this is developed by chemical process, permanent pictures may be printed from it. This is what is done in photography.

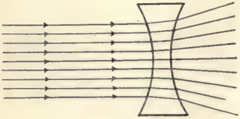


FIGURE 105

In the magnifying glass (Figure 106) the eye is placed near the lens and the rays from a small object are so bent that they appear to be spread apart and to come from a much larger object. The refracting telescope and the compound microscope (Figure 93) are combinations of magnifying lenses so adjusted as to produce the largest possible clear image of the object examined.

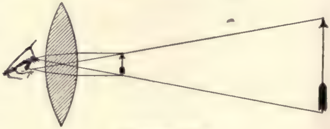


FIGURE 106

Light and Color. — **Experiment 106.** — Darken the room except for a small hole in the curtain where sunlight may enter. Allow the sunlight to pass through a glass prism and to fall upon a white wall or a piece of white paper. How has the white sunlight been affected? Where did the colors come from? In what order are the colors arranged?

Hold a piece of red glass close to the prism and between the prism

and the wall or paper. Do all the colors of the spectrum still appear? Repeat the experiment with glasses of other colors. What happens?

It was seen in Experiment 106 that when white light is passed through a prism it not only suffers a change in direction (is refracted), but it is also separated into different colors. White light must then be made up of lights of different colors, and the prism must have affected these colors so that each was bent to a different extent in passing through the glass. (Figure 107.) Careful experiments show

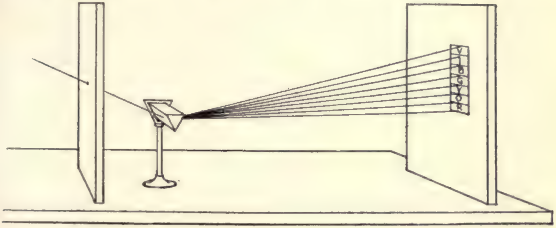


FIGURE 107

that light is a form of wave motion, and that the infinitesimally small wave-lengths of the various colors differ from one another. The colors are refracted differently in passing through the prism and are therefore separated from one another. The band of colors into which white light is separated by the prism is called the *spectrum.*

It was also seen that if the light from the prism was passed through red glass, all the colors except the red were cut off, or absorbed. If we could have made a careful test of the glass we should have found that it had been warmed by the absorption of these colors; that is, the energy of light had been transformed into the energy of heat. When light is

absorbed its energy is changed into heat energy or chemical energy.

Experiment 107. — Obtain pieces of cloth of a number of different colors. Darken the room and light a Bunsen burner. Adjust the holes at the bottom so that it will give but little light. Dip a glass rod in a solution of common salt and place it in the flame of the burner. The flame will be colored a brilliant yellow. Now examine the colors of the different pieces of cloth. Do they appear as they did in sunlight?

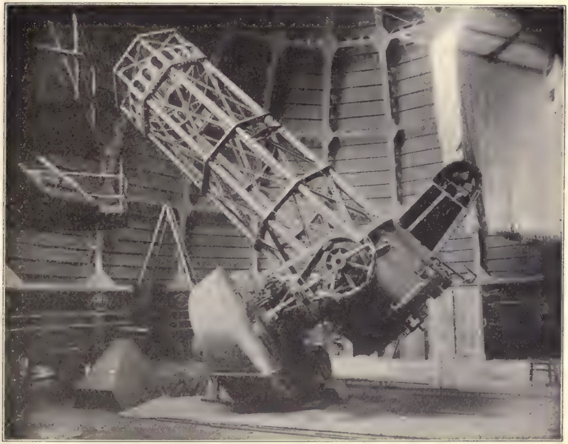
The color of a non-luminous substance is due to the kind of light it transmits or reflects. If a colored object is looked at by lamplight it will not appear of the same color as by sunlight because the lamplight is deficient in some of the colors of sunlight. Therefore the object cannot reflect the same combination of colors when exposed to lamplight that it reflects when exposed to sunlight.

If, for example, an artificial light lacks red rays, then a red surface exposed to it would absorb all the colors of the light and would appear black because there are no red rays to be reflected.

By combining the prism with the telescope, scientists have an instrument for examining the spectrum of the sun. With this instrument the spectrum is found to be crossed by hundreds of fine black lines scattered along the band of color. By bringing known elements to a white hot vapor and comparing their spectra with the spectrum of the sun, scientists have determined many substances that are in the sun.

Sunlight is affected by the air through which it comes. When the sun sets at night and the rays come to us through a great thickness of murky air which is near the surface of the earth, the light often appears red or yellow. The heavy

dust and smoke in the air has absorbed the other colors and has transmitted one of these two. On the top of a high mountain or on a clear day, or when the sun is high overhead, the sky appears blue. When the particles of matter in the atmosphere through which light is coming are



TELESCOPE EQUIPPED WITH A SPECTROSCOPE

It is with instruments like this that astronomers have been able to determine the composition of the sun.

very minute, blue is the color reflected. A blue sky indicates a clearer atmosphere.

Sometimes after a shower an arch appears in the heavens, composed of beautiful colors; we call this a *rainbow*. In this case the sunlight is broken into different colors by the drops of water which still fall in the distance, just as it is when passing through a prism.

Sometimes the sun or moon is surrounded by bright rings called, when of small diameter, *coronas*, and when of great diameter, *halos*. These rings are due to the effect of water or ice particles on the light coming from the sun or the moon.

Under certain conditions it may happen that light coming from objects at a distance is so refracted and reflected by the layers of air of different density, through which it comes

LICK OBSERVATORY

As light is affected by the atmosphere, observatories must be placed where atmospheric conditions are the best. This famous observatory is on a mountain in the clear air of California.

to the eye of the observer, that objects appear to be where they are not, like the image of a person seen in a mirror. This phenomenon is called *mirage* or *looming*. It occurs most frequently on deserts and over the sea near the coast.

Sometimes in high latitudes arches and streamers of colored light are seen illuminating the northern sky. The brilliancy and colors of the illumination vary. Sometimes it is bright enough to be seen even in the daytime. This display is called the *aurora borealis* or "northern lights"

and is believed to be an electrical phenomenon in thin air. The heights of the streamers have been calculated to be more than a hundred, perhaps several hundred miles, so that it is probable that air in a rare condition extends to this elevation.

Theories Concerning Light. — Although it is very easy to perceive light and to examine many of its properties, yet to determine just what it is that produces the light sensation has been found vastly difficult. Sir Isaac Newton thought that light consisted of streams of very minute particles, or corpuscles, thrown off by the luminous body. Since about 1800, it has been considered a form of wave motion which is transmitted through the ether which fills all space.

Light and Comfort. — In early days when few people were able to get glass for windows, houses were dark and gloomy. At present, however, glass is cheap and there is no reason why houses should not be well lighted. Few houses are built nowadays without making generous allowance for window space. All modern manufacturing buildings have the major part of their outside walls devoted to windows. Hospitals are so planned that every possible room may have direct sunshine for at least a part of every day. We are beginning to appreciate the value of abundant sunlight.

Dampness and darkness are the two conditions favorable to the growth and activity of bacteria. Few disease germs can live if exposed to the direct light of the sun. No house can have too much sunlight. There should be no dark corners to harbor germs. Kitchen cupboards and sinks should be so located, if possible, that they may receive direct sunshine. Bedclothes, rugs, hangings, clothing, should all be exposed to the bright sunlight as often as possible. Sun-

light not only kills disease germs; it also banishes gloom and stimulates cheerfulness. Cheerfulness itself is a genuine health tonic.

Up to about fifty years ago whale oil and candles furnished the best artificial lights obtainable. It is difficult for us to appreciate how numerous are the advantages and how much

Hospital Ward

Showing the great care taken to secure light, air, and cleanliness.

greater the power of illumination when kerosene, gasoline, acetylene, illuminating gas, and electricity are used. In many sections of our large cities artificial lighting almost turns night into day. So enormous is the amount of fuel used for the brilliant lighting of our cities that the United States Government was compelled to combine "lightless nights" with "daylight saving" in the interest of fuel economy during the World War.

Because of the brilliancy of many modern artificial lights, their inferiority to sunlight is often overlooked. It is very difficult to arrange artificial lights in libraries, schools, and public halls so that work may be carried on with as great ease in one section of the room as in another. Unshaded high-power lights may furnish sufficient illumination, but the effect is too dazzling. Scattered low-power lights give a more uniform and less trying illumination. Where central lights are to be used, translucent bowls which diffuse some of the light to the room and reflect some to the ceiling probably give the best results for general purposes.

An Old Whale Oil Lamp

It must be remembered that if the walls and furnishings of a room are dark in color much of the light will be absorbed and little reflected, and even bright lights will illuminate the room only in their immediate vicinity. Decorators have this fact in mind when they recommend lighter walls and hangings for north rooms than for south rooms.

Whatever kind of illumination is provided, the person using it must be careful not only that his work shall be properly lighted but also that his eyes shall be protected against direct glare. Too much care cannot be taken of the eyes. No arrangement of artificial light is as easy on the eyes or as reliable as daylight, where colors are to be worked with or where careful measurements or minute adjustments are to be made. In work of this kind, rooms with windows on the north side, through which only diffused light will come, are preferable to rooms lighted by south windows.

SUMMARY

The sun is the source not only of almost all the heat of the earth but also of practically all its light. Light is just as essential to life as heat is. No comprehensible figures will express the intensity of the sun's light, using the candle power as a measure. The intensity of light varies inversely as the square of distance from its source.

All objects except self-luminous bodies are seen by reflected light. Objects on the earth reflect both heat and light. The angle at which a ray of light is reflected is equal to the angle at which the ray strikes the reflecting surface.

Light travels at the rate of about 186,000 miles per second. When it travels through a uniform medium, it goes in a straight line; but when it travels through media of varying densities the rays are bent or refracted. The bending of light rays in passing from one medium to another is turned to great advantage in the use of lenses which may be so constructed as to bend rays of light in any desired direction.

When a ray of white light is passed through a prism, it is not only refracted but is also separated into different colors. Light is a form of wave-motion, and the infinitesimally small wave-lengths of the various colors differ from one another. This accounts for the different degrees of bending of the various color rays when passed through a prism. The band of colors into which white light is separated is called the spectrum. The color of a non-luminous substance depends on the kind of light it transmits or reflects. When a substance is brought to a white-hot vapor, it has a characteristic spectrum. By combining the prism with the telescope, scientists have an instrument called a spectroscope,

by means of which many of the substances in the sun have been detected.

Changing conditions of the atmosphere affect the colors of sunlight in various ways. Rainbows, halos, coronas, and mirages are owing to peculiar conditions of the atmosphere, through which light is coming to the eye.

Natural and artificial lighting of houses deserves the most careful consideration, for the sake of convenience, comfort, and health.

Questions

What experiences have you had which cause you to think that light travels in a straight line?

If a boy is reading two feet from a light and moves to a distance of eight feet, how much ought the strength of the light to be increased to enable him to read with the same ease?

How long does it take light to come from the sun to the earth?

What experiences have you ever had which illustrate refraction?

Why do not colors look the same in artificial light as they do in sunlight?

How would you arrange the windows, hangings, and artificial lights of a room to make it most healthful and cheerful?

CHAPTER XIII

LIFE ON THE EARTH

Plants and Animals. — Plants and animals are combinations of the earth's elements endowed with life. By means of the sun's energy they are able, the plants directly and the animals indirectly, to do both internal and external work which results in growth, reproduction, and other activities. Since plants and animals are entirely dependent upon the earth and sun for their existence, they, like other earth and sun phenomena, should be studied in this course.

Plants. — Although in their lower microscopical forms it is very difficult to distinguish between plants and animals, yet the forms ordinarily seen differ greatly. Most plants are fixed and consist of root, stem, and leaves, while most animals are movable and possess a variety of different parts. But some plants, like the seaweeds, appear to have no roots; some, like the dandelion, no plant stem, and some, like the cactus, no leaves.

If we dig around the base of a tree, we find in the soil a network of roots holding firmly erect a pillar-like stem with branches bearing a profusion of leaves. If we examine these divisions carefully, we shall find that each has a distinct part to play in the life work of the tree. We shall also find (1) that plants as well as animals need air, water, and other kinds of food, (2) that plants and animals take in, digest, and assimilate food, and (3) that each in the higher forms has parts

which are particularly adapted for doing these different kinds of work.

THE GRIZZLY GIANT

The monarch of all plants, 93 feet around the base. Notice the cavalry at the foot.

Plant Roots. — Plant roots usually secure the plant to the ground so that the stem may be supported. They also take up food from the soil and pass it on to the rest of the plant. In most plants all the foods except carbon and a part of the needed oxygen are taken in by the roots. The soil elements that the plants must have are nitrogen, potassium, calcium, magnesium, phosphorus, sulphur, and iron. Water supplies hydrogen and oxygen; while carbon, another necessary element, is taken from carbon dioxide of the air. The soil elements must be in soluble chemical combinations, such as nitrates, phosphates, sulphates, and so on.

Experiment 108. — Fill three 2-quart fruit jars each about half full of distilled water. Add to the water in the first of these $\frac{1}{2}$

gram of potassium nitrate, $\frac{1}{4}$ gram iron phosphate, $\frac{12}{100}$ gram calcium sulphate, and $\frac{12}{100}$ gram magnesium sulphate. Add to the water in the second jar the same ingredients with the exception of the potassium nitrate. Replace this by potassium chloride. Add nothing to the water of the third jar. Put the three jars where they will receive plenty of sunlight and warmth and place in each a slip of Wandering Jew about 10 inches long. Note which slip grows the most thriftily. In the third jar there is no mineral food, in the first all of this food which is necessary, and in the second all the necessary food except nitrogen.

A TYPICAL PLANT
Showing root, stem, leaf, and flower.

In Experiment 108, it was found that in the distilled water the plant made but little growth. Water and air alone are not sufficient. It did not thrive when the nitrogen was lacking, but grew very well when all the necessary elements were present. All plant foods, however, must be in dilute solution before plants can appropriate them.

Experiment 109. — In another fruit jar make a very strong solution of potassium nitrate or, as it is commonly called, saltpeter. Place in this a slip of Wandering Jew as was done in the previous experiment. Does the slip grow well? It has a great abundance of nitrogen, which was found so important. Place in a similar strong solution a growing beet or radish freshly removed from the ground. Notice how it shrivels up. Place a similar beet or radish in water. It is not similarly affected. What is the effect of strong solutions on plants?

If the solution is too strong, as seen in Experiment 109, the plant cannot use it. This is the reason many alkali soils will not support plants. The alkali salts are so readily soluble that the soil water becomes a solution stronger than the plants can use.


Roots Securely Holding the Tree Erect

Experiment 110. — Place three or four thicknesses of colored blotting paper on the bottom of a beaker. Thoroughly wet the paper and scatter upon it several radish or other seeds. Cover the beaker with a piece of window glass and put in a warm place. Allow it to stand for several days, being sure to keep the blotting paper moist all the time. When the seeds have sprouted, examine the rootlets, with a magnifying glass or low power microscope, for the root hairs which look like fuzzy white threads. Touch the root hairs with the point of a pencil. They cannot, like the rest of the root, stand being disturbed. On what part of the plant root do the root hairs grow? As the blotting paper dries, what happens to the root hairs?


Figure 108

Plant roots are enabled particularly by the little root hairs (Figure 108), which were examined in Experiment 110, to take the film of water which surrounds the soil particles and carry this water to the stem and, through it, to the leaves. The water which the roots take from the soil is a dilute solution containing the plant food substances. Not

only do roots absorb the water from the soil, but they secrete weak acids which aid in dissolving the mineral substances which the plants need. This can be seen where plant roots have grown in contact with polished surfaces, such as marble. These surfaces are found to be etched.

Experiment 111. — Cut a potato in two. Dig out one of the halves into the shape of a cup and scrape off the outside skin. Fill the potato cup about $\frac{2}{3}$ full of a strong solution of sugar. Mark the height of the sugar solution by sticking a pin into the inside of the cup. Place the cup in a dish of water. The water should stand a bit lower than the sugar solution in the potato cup. After the cup has stood in the water for some time, notice the change in the height of the denser sugar solution.

FIGURE 109

Experiment 112. — Bore a $\frac{3}{4}$-inch hole 3 or 4 inches deep in the top of a carrot. Scrape off the outside skin and bind several strips of cloth around to keep the carrot from splitting open. Fit the hole with a one-hole rubber stopper having a glass tube about 1 meter long extending through it. (Figure 109.) Fill the hole in the carrot with a strong sugar solution colored with a little eosin and strongly press and tie in the stopper. The sugar solution will be forced a short distance up the tube by the insertion of the stopper. Mark with a rubber band the height at which it stands. Submerge the carrot in water and allow it to stand for a few hours. Mark occasionally the height of the column in the tube. Taste the water in which the carrot was submerged. There has been an interchange of liquids within and without the carrot.

The plant root takes up its water in the same way the water was taken into the sugar solution of the potato cup or of the carrot. The water or *sap* within the substance of the root is denser than the soil water, just as the sugar solution was denser than the water outside. It has been found that whenever two liquids or gases are separated

by an animal or plant membrane, there is an interchange of the liquids or gases, the less dense liquid or gas passing through more rapidly. This is called *osmosis* and is of the greatest importance to both plants and animals.

All animals and plants are made up of exceedingly minute parts, called *cells*. Figure 110 shows the cells in a leaf and the leaf hairs greatly magnified. The higher plants and animals are composed of vast numbers of these cells. The cell usually has a thin cell wall, which in living and growing cells incloses a colorless semi-fluid substance called *protoplasm*. This protoplasm is the living part of the plant. It is found in all the cells where growth is taking place, where plant substances are being made, or where energy is being transformed. It has the power of dividing and forming new cells, and it is in this way that the plants grow.

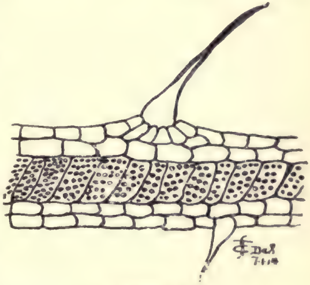


FIGURE 110

The little root hairs are one kind of plant cells. They consist of a thin cell wall within which is protoplasm and cell sap, a solution of different plant foods. Since the protoplasm and cell sap are denser than the soil water, more liquid moves into the cell than from it. A little of the cell solution does move out, however, and it is this which helps to dissolve the soil particles. The protoplasm in the cell regulates to some extent the interchange of liquids.

Experiment 113. — Cut off the stem of a thrifty geranium, begonia, or other plant an inch or two above the soil. Join the plant

stem by a rubber tube to a glass tube a meter long, of about the same diameter as the stem. See that the rubber tube clings strongly to both glass tube and stem. It may be best to tie it tightly to these. Support the glass tube in a vertical position above the stem and pour into it sufficient water to rise above the rubber tube. (Figure 111.) Note the position of the water column. Thoroughly water the soil about the plant. Watch the height of the water column, marking it every few hours.


FIGURE 111

The water taken in by the roots passes on from cell to cell by osmotic action and rises in the stem in the same way that the water rose in the tube attached to the stem of the growing plant in Experiment 113. The root pressure, together with *capillarity*, as seen in Experiment 97, will account for the rise of the sap in lowly plants, but the cause of the rise of the sap to the top of lofty trees is difficult to understand.

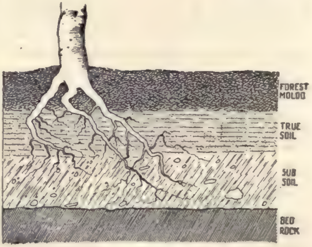


FIGURE 112

Roots extend themselves through the soil by growing at the tips. Here the cells are rapidly dividing, forming new cells, and building root tissue. As water is so essential, they are always seeking it and extending themselves in the direction where it is to be found. This causes them to extend broadly and to sink deeply (Figure 112). A single oat plant has been found to have an entire root extension of over 150 feet. This seeking of the roots for water sometimes causes the roots of trees to grow into drain pipes and stop them up.

For this reason the planting of certain trees near sewer pipes is often prohibited.

Experiment 114. — Boil some water so as to drive out the air and after it has become cool fill a 2-quart fruit jar half full. Dissolve in this all the necessary plant food as was done in Experiment 108, making the solution the same strength. Place in this a slip of Wandering Jew. Pour over the surface of the water a layer of castor oil or sweet oil. Place this jar alongside the slip in the other complete food solution, Experiment **108**. Both slips have the same conditions except that the oil keeps out the air from the roots of one of them. Does the absence of air affect the growth of the slip?

As the tips of the roots are delicate, it can be readily seen that if they are to grow readily the soil around them must be mellow. It was seen in Experiment 114 that if roots are to grow they must have air, another reason for keeping the soil mellow.

Roots are, however, not simply absorbers of water and dissolved food. Some of them act as storehouses for the food that the plant has prepared for future use. Beets, carrots, parsnips, turnips, and sweet potatoes are examples of roots which store food ready for the rapid growth of the next year's plant.

Stems. — **Experiment 115.** — Examine a corn stalk. Notice how and where the leaves are attached to the stem. Do the alternate leaves come from the same side of the stem? Cut a cross section of the stalk. Notice the outside hard rind, the soft pithy material, and the small firmer points scattered about in the pith. Cut a section lengthwise of the stalk and notice how these small firmer points are related to the lengthwise structure of the stem.

Cut off a young growing corn stalk and place the cut end in water colored by eosin or red ink. Allow it to stand for some time and then cut the stalk off an inch or two above the surface of the water. How have "the firmer points" been affected? If possible,

A Pine Tree

Notice the erect position of the stem.

make the same observations and experiments on the stem of a small seedling palm tree.

Experiment 116. — Examine a piece of the growing young stem of a willow, apple tree or other woody stem that shows several leaf scars. Is the arrangement of the leaves the same as in the corn stalk? Cut a cross section of this stem and examine it. Does it resemble the cross section of the corn stalk? Strip off a piece of the bark and compare it with the rind of the corn stalk. Examine carefully the smooth, slippery surface of the wood just beneath the bark. This is the *cambium layer*.

Examine the firm wood beneath this layer. Where is the pith in this stem? With a lens you may be able to see lines radiating from the pith to the circumference of the stem. These are called the *pith rays*. Cut a lengthwise section of the stem and examine it. Are there any fiberlike bundles as in the corn stalk? Cut off a piece of the stem already examined having the bark on it, or a piece of sunflower stem, and place the end of it in colored water. Allow it to remain for some time and then cut a cross section above the point where it was in the water.

Has the water risen and colored this cross section as it did the cross section of the corn stalk?

Stems vary greatly in the positions they assume. Some rise firmly erect from the root, like the oak and the pine; some cling to supports, like the grape and the ivy; some twine around supports, like the bean; some creep upon the ground, like the strawberry; some grow in the form of a thickened bulb like the onion (Figure 113); some, like the cacti, assume a fleshy, leaflike, though leafless form; some, like the nut grass, Johnson grass, and witchgrass, grow underground and send up shoots, and some stems store up food underground in tubers, like the potato (Figure 114), from which the next year's plant may grow.

FIGURE 113

FIGURE 114

Notwithstanding all the diversity shown by the stem, its principal functions are to support the leaves, so that they will best be exposed to the light, and to conduct the food solutions from the root to the leaves. The part of the stem through which the cell sap flows was seen in Experiments 115 and 116.

There are two great types of stems, one represented by the corn stalk and palm and the other by the willow, sunflower, and bean. On account of the structure of the seeds these are called, respectively, *monocotyledonous* (one seed leaf) and *dicotyledonous* (two seed leaves). That these differ greatly in their appearance was seen in Experiments 115 and 116, where the two kinds of stems were compared. It was also found in these experiments that, in the first, the red colored water that took the place of the sap rose in the fibrous bundles scattered through the

pith, while in the second it rose through the woody tissue within the bark.

Experiment 117. — Examine a cross section of a hardwood tree several years old, and if possible of a palm. Notice the ringlike arrangement of the layers in one and the absence of all such arrangement in the other.

In Experiment 117, when the cross section of a dicotyledonous tree was examined, it was found to be composed of circular rings, but no such rings are found in the cross

A Splendid Tree Developed under Ideal Conditions

section of the monocotyledonous tree. When later we examine the seeds of beans and corn, we shall find that they also differ very much.

When the bark is removed from a stem, like the willow or apple, the soft, smooth layer underneath is found to be

Banyan Tree

Some of the branches descend and take root in the ground and so appear like stems.

composed of living cells. This is called the *cambium layer*. During the season of growth, these cells are continually subdividing and forming new cells, thus adding a ring to the thickness of the stem. The age of a tree can be determined by counting these rings. No such layers are found in the monocotyledonous stems. *Grafting* (Figure 115) and *budding* (Figures 116 and

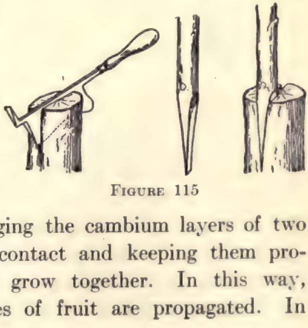


Figure 115

117) are processes of bringing the cambium layers of two trees of similar kinds in contact and keeping them protected so that they will grow together. In this way, many of our finest species of fruit are propagated. In

fact, fruit trees raised from seed are not exactly like the parent tree, and if trees are to be true to variety they must be propagated in this way.

Experiment 118. — Examine several growing stems or twigs which have buds upon them and notice how the buds are arranged. Is the arrangement the same in all? If these buds grew into twigs or leaves, would they shade one another? Is there a bud at the end of the twig or stem?

If we examine the tip of a growing stem or twig, we shall find a *bud*. In most of the trees and shrubs of temperate regions a terminal bud is formed at the close of

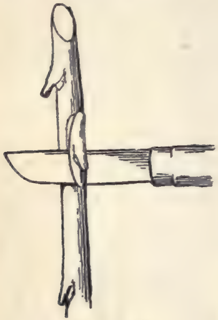


FIGURE 116

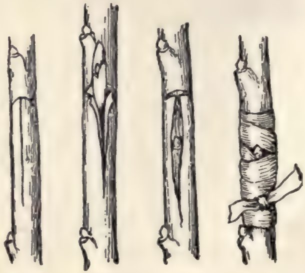


FIGURE 117

the growing season, and from this the shoot continues to grow the following season. Buds are also found along the length of the stem and branches, as was seen in Experiment 118. These are lateral buds and, since they are usually found in the axis of the leaf, at the angle formed by the leaf and stem, they are called *axillary*. In some trees the terminal buds die at the end of the growing season,

and the next year's growth is due to one of the axillary buds.

Leaves. — If we examine the arrangement of the leaves on a plant or tree, we shall see that they do not lie one directly above the other, but that they are so arranged as not to shade one another. Their position generally is such that the broad upper surface of the leaf receives the strong light rays perpendicularly upon it. To accomplish this, the leaves in many trees are arranged spirally around the stem.

DIFFERENT FORMS WHICH LEAVES ASSUME

The stem of the leaf itself, in some parts of the tree, often grows long and twists about, in order to push the leaf out to the light and yet not let it be wrenched away by the wind. The horse-chestnut is such a leaf. In some plants, like the sunflower, the younger leaves follow the sun all day. In other plants the rays of the sun seem to be too bright in the middle of the day and the leaves are then held edgewise to the light.

A striking example of this is the compass plant, the leaves of which arrange themselves so that the sun's rays strike the broad surface of the leaves in the evening and morning when the rays are not very strong, but at noon the

edge of the leaf is toward the sun, the leaf thus maintaining a nearly vertical position all day, with its greatest length extending in a nearly north and south line. It is the effort to regulate the amount of light falling on the leaf, and not any magnetic influence, which causes the leaf to point in the direction of the compass needle.

Figure 118

The shapes of the leaves vary greatly in different plants. Sometimes they assume very singular forms, as in the pitcher plant (Figure 118) and Jack-in-the-pulpit. Sometimes they even become carnivorous, as in the sundew and Venus flytrap.

Around the margin of the sundew leaf and on the inner surface are a number of short bristles, each having at the end a knob which secretes a sticky liquid. As soon as an insect touches one of these knobs, it sticks to the knob and the other bristles begin to close in upon the insect and hold it fast. Soon the insect dies and the leaf secretes a juice which digests the soluble parts of the insect.

Figure 119

In the Venus flytrap (Figure 119) the leaf terminates in a portion which is hinged at the middle and has on the inside of each half three short hairs, while the outside is fringed by stiff bristles. As soon as an insect touches the hairs,

the trap closes rapidly upon it and stays closed until as much as possible of the insect is digested, when the trap again opens. Carnivorous plants of this kind usually grow in places where it is difficult to get nitrogenous foods. As nitrogen is absolutely necessary for the growth of protoplasm (page 371) these plants may have had to adopt this way to supply the need.

FIGURE 120

Some leaves extend themselves into spiny points, like those of the thistle (Figure 120), in order to keep animals from destroying the plant, or they may develop a sharp cutting edge, like some grasses, or emit a bad odor, or have a repugnant, bitter taste.

The veins or little ridges extending through the leaf from the leaf stem vary (Figure 121). Sometimes these veins extend parallel to one another through the leaf, as in the corn and palm. This is generally characteristic of monocotyledonous leaves. In other leaves, the veins form a network, as in the maple and apple. This is .characteristic of dicotyledonous plants.

FIGURE 121

Experiment 119. — Place the freshly cut stem of a white rose, white carnation, variegated geranium leaf, or any thrifty leaf which is somewhat transparent, in a beaker containing slightly warmed water strongly colored with eosin. Allow it to remain for some time. The coloring matter can be seen to have passed up the stem and spread through the leaf or flower.

The great function of the leaf is to manufacture plant foods. The leaf is so constructed that air can enter it and come in contact with its living cells, as does the water coming up from its roots. The circulation of water in the leaf was seen in Experiment 119. There is in the living cell of the leaf a green substance called *chlorophyll*. This has the power to utilize the energy of sunlight and to combine the carbon and the oxygen of carbon dioxide taken from the air with the hydrogen and the oxygen of water taken from the soil, thus forming a substance which probably at first is grape sugar, but which in many leaves is changed at once into starch.

Experiment 120. — Boil a few fresh bean or geranium leaves for a few minutes in a beaker of water. Pour off the water and pour on enough alcohol to cover the leaves. Warm the alcohol by putting the beaker in a dish of hot water. When the leaves have become colorless, remove from the alcohol and wash. Place the leaves in another beaker and pour on a solution of iodine. (This solution can be made by dissolving in 500 cc. of water 2 grams of potassium iodide and ½ gram of iodine. The solution should be bottled and kept.) If the leaves turn dark blue or blackish, starch is present.

Experiment 121. — Place a thrifty geranium or other green plant in darkness for two or three days and then treat the leaves as was done in Experiment 120. Do they show the presence of starch? The direct presence of the sun's energy in the form of light is necessary for the formation of starch in the leaves.

It was found in Experiment 120 that leaves exposed to the sun contained starch, and in Experiment 121 that leaves which had been deprived of sunlight did not have starch. The starch disappeared while the plant was in darkness. Not all of the oxygen from the carbon dioxide and the water is used in the manufacture of starch by the chlorophyll, and so some of the oxygen becomes a waste

product which the leaves throw off. This will be seen in Experiment 122.

Experiment 122. — Under an inverted funnel in a battery jar, place some pond scum or hornwort. Fill the jar with fresh water and over the neck of the funnel place an inverted test tube filled with water. (Figure 122.) When placed in the sunlight, bubbles of oxygen will rise into the test tube and collect. The oxygen can be tested by turning the test tube right side up and quickly inserting a glowing splinter. If the splinter bursts into a flame, oxygen is present. (A freshly picked leaf covered with water and put in the sunlight will be seen to give off these bubbles.) After a small amount of gas has been collected in the test tube, mark the height of the water column and place the battery jar in the dark, allowing it to remain there for ten or twelve hours. No oxygen is given off in the dark. Place the jar in the light again. Oxygen is given off. Is the sun's energy needed to enable the plant to give off oxygen?

FIGURE 122

The starch manufactured is insoluble in water and is stored in the leaf during the day. But at night, when the leaf is not manufacturing starch, it is able to digest the starch by means of a special substance, *leaf diastase*, which it forms. This changes the starch into sugar, which is soluble and which is carried in solution to other parts of the plant. Compounds such as starch and sugar, in which there are only carbon, hydrogen, and oxygen, are called *carbohydrates*.

The cells in the leaf and in other parts of the plant have the power to change the sugar and combine it with other substances contained in the sap, thus forming more complex chemical compounds. These contain nitrogen and sulphur, besides the elements of the sugar. Such compounds are called *proteins*. They are essential to the formation of plant protoplasm and are very important as animal foods.

The digested and soluble substances which are prepared by the leaves are transported to other parts of the plant, where they are combined by the protoplasm of the living cell with other substances contained in the cell sap. Thus the protoplasm itself is able to increase and form new cells as well as other substances, such as woody tissue and oils and resins. In forming these substances the plant requires

A PINE FOREST

From the pitch in these trees turpentine and tar are made.

oxygen just as animals do. If air is kept from the roots of certain plants, as was seen in Experiment 114, the plants cannot live.

These food substances which plants make by using the energy supplied by the sun are the bases of all plant and animal life. The sun's energy stored up in the green leaf is the source of all plant and animal energy. If it were

not for the leaf manufactory run by the sun's power, life, as we know it, would cease. Even plants that lack chlorophyll, like the mushroom, must live on the food manufactured by the chlorophyll of the green plants.

Experiment 123. — Procure a small, thrifty plant growing in a flower-pot. Take two straight-edged pieces of cardboard sufficiently large to cover the top of the flowerpot and notch the centers of the edges so that they can be slipped over the stem of the plant and thus entirely cover the top of the flowerpot. Fasten the edges of the cardboard together by pasting on a strip of paper. The top of the pot will now be entirely covered by the cardboard but the stem of the plant will extend up through the notches of the edges. Cover the plant with a bell jar. (Figure 123.) No moisture can get into the bell jar from the soil in the pot, as it is entirely covered. Set the plant thus arranged in a warm, sunny place. Moisture will collect on the inside of the bell jar. This must have been given out by the plant leaves.


FIGURE 123

Since all the processes of forming new material by the plant require large amounts of water, it can readily be seen why water is so essential to plant development. The water from which the food materials have been taken is thrown off by the leaves, as seen in Experiment 123. The amount of water thus thrown off by plants is very great. A single sunflower plant about six feet tall gives from its leaves about a quart of water in a day, and an acre of lawn in dry, hot weather gives off probably six tons of water every twenty-four hours.

If the water passes out of a plant too rapidly so that

there is not enough left to provide for the making and transporting of the food, the work of the plant cannot be carried on, and the plant dies. It is on account of this that many plants are especially prepared to retain their water supply. In almost all plants the *stomata,* or little pores in the leaf through which the water passes out, close up when too much water is being lost.

In some plants, like the corn, when the root cannot supply sufficient moisture, the leaves curl up and thus present less surface for evaporation. In trees like the eucalyptus the leaves hang vertically when the sun gets too bright and present their edges to the sun's rays. Some leaves, like the sage, are especially prepared to conserve their moisture by having their surfaces covered with hairs. Others have a waxy covering, as the cabbage and the rubber tree. In some plants the leaves are very small and have few pores, as the greasewood of the desert, and some have done away with leaves altogether, as the cactus. It is because the roots cannot supply sufficient moisture where the ground freezes in the winter that trees having large leaves shed them. Only trees like the pine, whose needle-like, waxy leaves give off almost no moisture, can retain their leaves.

A Sunflower Plant

Flowers. — The stem not only bears leaves but, in the higher kinds of plants, it bears flowers. The function of the flower is to produce seeds and provide for the continued existence of its kind. If the flower of a buttercup, quince, cassia, or geranium is examined, it will be found to be made up of four distinct kinds of structures.

EUCALYPTUS LEAVES

Around the outside is a cluster of greenish leaves. This is called the *calyx*. Within the calyx is the *corolla*, a cluster of leaves which in many plants are colored. Within the corolla are a number of parts consisting of a rather slender stalk with an enlarged tip. This tip is called the *anther*, and the stalk and anther together, the *stamen*.

FLOWER SHOWING DIFFERENT PARTS

In the center of the flower are the *pistils*. At the top of a pistil is generally a somewhat enlarged portion, the *stigma*, which is sticky or rough; and at the bottom there is an enlarged hollow portion, the seed-bearing part, called the *ovary*. These two parts are connected by the stalklike *style*. The stamens and pistils are the essential parts of the flower, the calyx

and corolla being simply for protection or assistance. All flowers do not have these four parts, but every flower has either stamen or pistils or both.

Pink Gentian

Showing the anthers, which are covered with pollen.

The anther produces a large number of little granular bodies, called *pollen grains*, each of which consists of a free cell containing protoplasm. When the pollen grains are ripe, the anther opens and exposes them. If a pollen grain of the right kind falls upon a stigma it grows and sends down a tiny tube through the style into the ovary, where a little protoplasmic cell, called the *egg cell*, has been produced. The essential parts of these two different kinds of protoplasms unite and a new cell is formed.

Mint Flower

This new cell grows and divides into more cells, thus forming the young embryo of a new plant. This embryo is the living part of the seed and around it usu-

ally a great deal of plant food is stored, so that when it begins to grow it will have plenty of nourishment until it is able to develop the roots and leaves necessary to prepare its own food.

Embryos cannot be produced unless pollen grains and egg cells unite, so it is absolutely essential that the right kind of pollen grains be brought to the stigma. Some stigmas are able to use the pollen grains produced by the anthers of their own flowers, but others can only use pollen from other flowers and other plants. It is therefore necessary that these pollen grains be carried about from flower to flower if fertile seeds are to be produced.

Ear of Corn

Each kernel is the result of a wind-blown pollen grain falling upon a corn-silk.

In some cases the pollen is borne about by the wind, as in the case of corn. In this way an exceedingly large number of pollen grains are wasted, as can be seen by the great amount of yellow pollen scattered over the ground of a cornfield when the corn is in bloom. In the corn each one of the corn silks is a pistil and a seed is produced at its base if a pollen

grain lights upon the stigma at its upper extremity. The flowers of walnut and apple trees are fertilized by wind-blown pollen.

The pollen of very many plants, however, is carried about by humming birds, bees, and other insects. As the bee crawls into the flower to get the nectar at the bottom, it brushes against the anther and some of the pollen grains become attached to it. These, later, are rubbed off by the rough or sticky stigma of another flower which the bee enters and thus the flower is fertilized. The humming bird, by reaching its long, slender beak down into the long, narrow tube formed by the corolla of the "wild honeysuckle" (Figure 124), brushes upon the stigma the pollen grains it has obtained from another flower and thus distributes pollen from flower to flower. In no other way could these plants be fertilized.

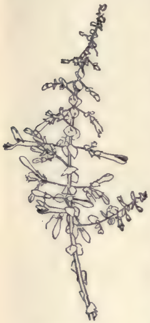


FIGURE 124

The beautiful colors of flowers and the sweet nectars that many of them secrete are the adaptations of the plant for enticing insects to enter them and bring to their stigma the pollen from other flowers, or take from their anthers pollen needed to fertilize another similar plant.

FIGURE 125

Some flowers are so constructed that only certain insects can fertilize them; the wild honeysuckle requires the humming bird, the red clover the bumblebee (Figure 125), and other plants, other kinds of insects. Flowers of some varieties of plants cannot be fertilized by flowers of a like variety. Certain varieties of strawberries,

for example, need to have other varieties planted near them, if they are to prosper. Some plants need not only to have other varieties planted near, but they also require the presence of special insects.

One of the most striking examples of this is the Smyrna fig. For many years attempts were made to introduce this fig into California. The trees grew but the fruit did not mature. It was then observed that in the regions where this fig was successfully grown a species of wild fig was abundant and that the natives were accustomed to hang branches of the wild fig in the Smyrna fig trees at the time they were in flower. These wild fig trees were brought to California and grown near the Smyrna fig trees, but still figs did not mature. Upon further examination it was observed that at the time of flowering a small insect issued from the wild figs and visited the flowers of the Smyrna figs. This insect was brought to California and now it is possible to grow figs. The flower of the Smyrna fig has no stamen and it is necessary for the wild fig to furnish the pollen which is only successfully carried to the stigmas of the edible fig by the small fig-fertilizing insect.

A somewhat similar case is that of the yucca found in the dry region of southwestern United States. This flower can be fertilized only by the aid of a small moth which flies about at night from flower to flower. It enters the flower, descends to the bottom, stings one of the ovaries, deposits an egg, then ascends and crowds some pollen on the stigma. The grub, when it hatches from the egg, feeds on the seeds in the ovary, but as there are many seeds in the flower which have been fertilized and the grub eats only a few of these, the moth has made it possible for the yucca to produce seeds sufficient for its continued propagation, which

YUCCA OR SPANISH BAYONET

would be impossible if it were not for the moth.

These are only a few of the vast number of cases which show the close relationship existing between plants and animals and the dependence of the one upon the other.

Seed Dispersal. — Not only must flowers produce fertile seeds, if the plants are to continue to exist, but these seeds must be scattered. To do this the seed pods of some plants suddenly snap open and spread their seeds. The touch-me-not and pea are examples of this. In some plants, like the maple, the seeds are winged (Figure 126) and float for some distance in the air. Others, like the thistle and the dandelion, have light, hairlike appendages which enable them to float away. In the case of the tumbleweed (Figure 127) the plant itself is blown about, scattering the seeds over the fields as it bumps along from place to place.

FIGURE 126

Some seeds are provided with hooks or barbs, like the beggar's-ticks (Figure 126), which attach the seeds to animals so that they are carried to a distance. Seeds having an

edible fruit cover, such as the cherry, blackberry, and plum, are eaten by birds and animals and the undigested seed deposited far away from the place where the seed grew. Seeds like the acorn are carried about by squirrels and other animals. Many seeds are able to float in water for a considerable time without being injured and are borne about by currents. Shores of streams and islands receive many of their plant seeds in this way. The cocoanut palm is a notable seed of this kind and is found widely scattered over tropical islands.

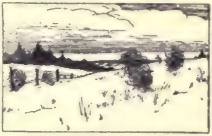


FIGURE 127

Seeds and Their Germination. — **Experiment 124.** — Take two common dinner plates and place in the bottom of one of them two or three layers of blotting paper and thoroughly wet it. Place some wheat or other kinds of seeds upon this. Now invert the other plate over the first, being careful to have the edges touch evenly. This makes a moist chamber and gives the most favorable conditions for germination. Do all the seeds germinate at the same time? Does the position of the seed make any difference? What takes place first in the process of germination? What appears first, the leaf or the root? Why does the seed shrivel up?

SCRUB OAK BRANCH

Showing the acorns.

Experiment 125. — Cut open several seeds, such as

pumpkin, squash, bean, corn, and drop on to the inside of each a few drops of the iodine solution made in Experiment 120. Do the seeds show the presence of starch?

Experiment 126. — Soak some beans for about twenty-four hours. Rub off the skin from two or three and examine their different parts carefully. Plant the beans in a box of damp sawdust. Put the box in a warm place. Plant some corn that has been soaked for two or three days in the same box. After the seeds have been planted several days, carefully remove a bean and a grain of corn and examine. Make a sketch of each of the seeds.

After a few days more remove another seed of each and examine and sketch. Continue to do this until the little plants have become quite well grown. Do the two seeds develop alike? Which of the seeds has two similar parts? These two parts are called *cotyledons.* What appears to be the use of these parts to the sprout? Consult the results of Experiment 124. Note the root development in each seed and the stem development. The sprouts get their food from the seed.

FIGURE 128

When we examined the different seeds in Experiment 125, we found that they each contained starch. When the seeds were soaked and planted, we found that a part of the seeds began to grow, forming a *sprout.* This part is the embryo already described. We also saw that the bean seed divided into two like parts which gradually withered and shrank, as the sprout grew, while the corn had only one such part.

These parts are called *cotyledons*, or seed leaves. The bean seed (Figure 128) is a *dicotyledon* (two seed leaves) and the corn a *monocotyledon* (one seed leaf). These cotyledons are the food storehouses for the germinating seed. As the sprout grew, the root, with its root hairs, developed,

and the stem with its leaves. When these had grown strong enough, the cotyledons, having performed their part, dropped off. The plant was now ready to prepare its own food by the aid of the sunlight.

Experiment 127. — Place several beans in a tumbler of damp sawdust and put it in a warm, light place. Keep the sawdust moistened. After the beans are well sprouted, with a sharp knife cut one of the half beans or cotyledons off from a sprout. Cut both cotyledons off another sprout. Put the sprouts back on the sawdust. Do the sprouts grow as well as those of the other beans?

Experiment 128. — Fill a 16-ounce, wide-mouth bottle about one third full of peas or beans. Pour in more than enough water to cover them. Tightly cork the bottle and put in a warm, sunny place. Put another similar corked empty bottle beside it. Allow the bottles to stand for several days until the peas have sprouted. Remove the cork from the bottle containing the peas and insert a burning splinter. Do the same to the empty bottle. Why does not the splinter burn as well in each? If on being placed in either bottle the splinter is smothered out, it shows the presence of carbon dioxide.

Experiment 129. — Fill two 8-ounce, wide-mouth bottles each about one third full of coarse sawdust and fill the remaining part with peas which have been soaked for a day. Pour in sufficient water to cover the sawdust. Cork one of the bottles tightly, leaving the other open. Put the two bottles in a warm, sunny place. Whenever necessary, pour on sufficient water to keep the sawdust in the open bottle wet. In which bottle do the seeds sprout the better? Does air appear to be necessary for the growth of seeds? As determined by the previous experiment, what part of the air is used?

We found in Experiment 127 that if the cotyledons were cut off before the sprout had become sufficiently mature, it could not continue its growth. In Experiment 128 we found that the sprouting seeds took up oxygen from the air and gave out carbon dioxide just as animals

do. Energy was needed and this energy was obtained by combining the carbon in the seed with the oxygen in the air, as it is when wood is burned. We found in Experiment 129 that the seeds could not sprout well unless sufficient air was supplied. That was because there was not enough oxygen supplied to furnish the necessary energy.

Experiment 130. — Place several sprouted seeds in each of two tumblers nearly filled with damp sawdust. Put these tumblers side by side in a warm, light place. Cover one of the tumblers with a box painted black so as to exclude the light. In which do the seeds grow the better?

After the seeds were sprouted and had begun to prepare their own food, it was found in Experiment 130 that they were not able to do this unless exposed to the light of the sun. The parent plant had stored, in a latent form in the seed, energy which it had received from the sun. This potential energy the sprout was able to change into the kinetic form by the aid of oxygen, and to use in the work of growing. After this latent energy had been expended, it had to fall back upon the direct energy of the sun which came to it in the form of sunlight.

Dependent Plants. — **Experiment 131**. — Expose a piece of moist bread to the air for a short time and then put it into a covered dish so as to retain the moisture. Does any change take place in the bread? Examine with a magnifying glass the mold which appears.

Experiment 132. — (1) Bruise a sound apple and place the bruised part in contact with a thoroughly rotten apple. Wrap the two up together in a wet cloth and put in a fruit jar. Seal the jar to prevent the water from evaporating. (2) Plunge a pin repeatedly first into a rotten apple and then into a sound one. Wrap the sound apple in a wet cloth and seal in a fruit jar. (3) Place a lemon which has developed a green, spongy, rotten place in it in contact

with a perfect lemon and keep them where they will be moist. What happens to the sound fruits?

The plants that we have so far studied are green plants and contain *chlorophyll*. They are able to prepare their food from the air and soil by the aid of the sun's energy. There is, however, another great group of plants which may be called dependent plants. They have no chlorophyll

Mistletoe Growing on an Oak

An interesting parasitic plant.

and are obliged to live upon the food that green plants have prepared. They find this food either in the living or in the dead parts of plants or animals, the animals having digested it from plants or other animals, who originally obtained it from plants. If plants live upon living plants or animals, they are called *parasites*, if upon dead ones, *saprophytes*.

We are most of us familiar with some of the larger de-

pendent plants, or fungi, such as the mushrooms (Figure 129) and toadstools. Mushrooms are widely used as a delicacy and their growth is an important industry in some sections. They are grown in soils very rich in humus and generally in dark, cellarlike places. The mushrooms that grow wild in the woods are abundant in some localities but should not be used for food unless most carefully examined by some one who is expert in determining the different species. There are several species of mushrooms which are exceedingly poisonous. For one of these there is no known antidote. The general structure of these larger fungi can be seen by examining a mushroom obtained from the market.

FIGURE 129

The *bacterium* is a single-celled dependent plant, probably the simplest of all plants; it can be seen only with a high-power microscope. Bacteria are rod-shaped, thread-shaped, screw-shaped, or have various other forms (Figure 130). The protoplasm in the cell of bacteria has the power to assimilate food and build more protoplasm. When the cell has grown sufficiently, it divides into two cells.

FIGURE 130

A healthy bacterium grows fast enough to be ready to divide about once an hour. If it divided once an hour and each division continued to divide once an hour, in the course of twenty-four hours there would be nearly seventeen million bacteria produced. If this were kept up for some weeks, the mass

of bacteria would be as large as the earth. Of course, this would mean that each bacterium had plenty of room to live in and plenty of food to live on and nothing to injure it. These conditions are not found, and each bacterium has to struggle for existence just as every other plant does. As it is, however, bacteria are numberless.

Some of the activities of soil bacteria we have already studied. There are many other kinds of bacteria, and the relations of many of them to man are of such importance that they will be given further attention in another chapter.

Molds are made up of many cells, and reproduce themselves by producing *spores*. If the mold on bread is allowed to grow for a long enough time under favorable circumstances, you will note a fine black powder that forms. The particles of this powder are spores (seedlike bodies) which will themselves grow into molds if favorable conditions are offered. Mushrooms reproduce by means of spores.

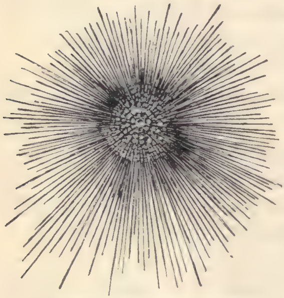
Yeasts are single-celled plants, as are bacteria, but they do not increase as bacteria do. A little bud forms on the side of the yeast cell, which grows until it finally separates from the parent cell. In this way a single yeast cell may produce several other yeast cells, whereas a single bacterium may only divide into two.

Animals. — Animals do not take their energy directly from the sunlight, but indirectly from the latent energy stored up in the foods prepared by green plants. These foods may be eaten as stored by the plants, or they may have passed through the medium of other plants and animals. The energy thus stored up is liberated by combining the carbon with oxygen. Carbon dioxide is freed.

The green plants use this carbon dioxide again and, by

the aid of the sun's energy, free the oxygen and store up the carbon. Thus the cycle goes on, over and over, the plants freeing oxygen and taking up carbon dioxide, and the animals freeing carbon dioxide and taking up oxygen. The cells of plants which feed upon the food prepared by the chlorophyll of the leaves use oxygen and give out carbon dioxide just as the animal cells do; so also do other plants to some extent.

Classification of Animals. — For convenience of study the animal kingdom has been divided into two great classes — the *invertebrates* (without backbone) and the *vertebrates* (with backbone). The invertebrate is the much more numerous class as it contains the worms, shellfish, insects, and those almost countless forms of animal life which have no internal bony skeleton and backbone. The higher animals, like fishes, amphibia, reptiles, birds, and mammals, belong to the class of vertebrates. Man himself is the highest of the vertebrates, and his structure will be studied later.



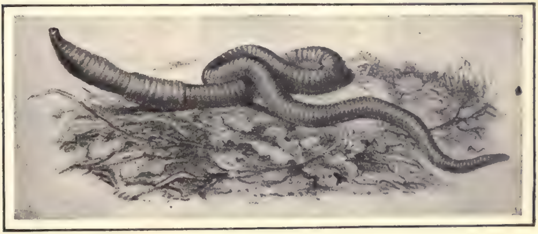
GLOBIGERINA (Greatly magnified)
The shells of these minute animals cover much of the ocean floor.

Invertebrates: Protozoa. — The very lowest forms of animal life, the protozoa, are single-celled animals. In some species they are very difficult to distinguish from plants of the lowest orders. They are microscopic in size and most of them live in water. Some of these tiny protozoa living in the sea are covered

by an extremely thin shell of lime. When they die, their shells sink to the bottom of the sea. So rapidly do these animals multiply that their minute shells have made thick layers of chalk like the famous chalk cliffs of the south of England.

Our chief interest in protozoa in the present study is that certain of them are the cause of several kinds of disease which can readily be prevented with proper care. Malaria and the terrible African disease called *sleeping sickness*, and probably yellow fever, are caused by these little animals. We shall study them more fully later in connection with harmful bacteria.

Worms. — Another class of invertebrates is the *worms*. One of these, the earthworm, was found in the study of soil making to be very important and should be considered



EARTHWORM

A great helper to the farmer.

in this place. If an earthworm is examined, it will be seen that the body is made up of segments or rings, and that it moves by successively shortening and elongating its body. Extending through the middle of the body is

an alimentary canal consisting of a mouth, gizzard for grinding food, stomach, and intestines.

Near the head is a little nerve center. The whole animal may be regarded as built up by the joining of a number of essentially similar segments. A more minute examination will show that these segments have been materially modified in some portions of the animal, but they have not been in any respect organized, as have the different parts of higher animals. This simple animal, as has already been seen, is an untiring worker in preparing and fertilizing soil for plants, and thus is a most efficient helper to man.

BUTTERFLY ON ALFALFA

Insects. — **Experiment 133.** — Procure a grasshopper or honey-bee, as a type insect, and inclose it in a small, glass-covered box. Into how many parts is the body divided? Describe these parts. To which part are the legs attached? The wings? How many legs are there? How many wings? Notice the largest part into which the body is divided. Notice the eyes and the feelers, or *antennæ*, on the head. Write a short description of the general characteristics of the bee's body.

The *insects* are among the most important of animals. This class contains more than half the known animal species. They are spread widely over all parts of the earth.

Both good and bad insects abound. Economically, they furnish millions upon millions of dollars' worth of produce every year and on the other hand destroy hundreds of millions of dollars' worth of crops and trees. It has been estimated that in the United States insects destroy every year crops and trees which have a value of $50,000,000, to say nothing of the countless losses due to diseases spread by flies and mosquitoes. (Page 452.) Not many years ago grasshoppers nearly devastated several of the middle western states.

FIGURE 131

The most productive insects are the silkworms and the bees. Without the silkworm (Figure 131) there would be no silk produced, and without the bee, no honey. These two products each year run into hundreds of millions of dollars. We have already seen that bees and other insects are needed also for the fertilization of flowers.

Among the most interesting of the insects and perhaps, everything considered, the most valuable, is the *honey-bee*. This is the great flower fertilizer; it would fertilize about all the plants man really needs except the red clover. In the United States alone there is produced by it about twenty-five million dollars' worth of honey and wax each year.

In Experiment 133, it was found that the body of the bee, like other insects, is divided into three parts. These parts are called head, thorax, and abdomen. The eyes

and the feelers, or antennæ, are on the head. The mouth is a very complex organ, fitted both for biting and for sucking. The six legs and four wings are on the thorax. The hind leg of each working bee is so shaped and fringed with hairs that it forms a pollen basket.

Honey-bees live in large colonies and in the colony there are three kinds of bees, the male bees, or drones, the workers,

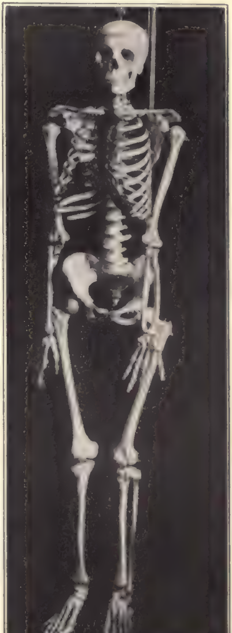
BEEHIVES

Hundreds of dollars' worth of honey are produced here each year.

and the queen or female bee. The workers are the ones that make all of the honey and wax, do all the work of the hive and feed the grubs on rich food formed in their own stomachs, as well as on pollen mixed with honey. The grubs are the first stage in the development of the bee from the egg. The queen lays all the eggs, sometimes as many as a million. There is but one queen in each swarm. Whenever another queen is ready to be hatched, the old

queen takes about half the colony and goes off to form another swarm.

The wax is secreted from glands in the abdomens of the workers and with this the bees build the comb. Each cell is hexagonal in cross section and the comb is so constructed that the least possible amount of wax will inclose the greatest possible amount of honey. The nectar at the bases of flowers supplies the bee with the material from which it makes the honey. It is in seeking for this that the bee visits so many flowers and scrapes the pollen on to the different parts of its body to be borne away to fertilize other flowers which it enters. Such an interesting animal and so exceedingly useful is the bee that hundreds of books have been written about it, more than about any other domestic animal. Some of these should be read for further information concerning this most instructive animal.



A HUMAN SKELETON

Notice how the bones are arranged to protect the delicate organs.

Vertebrates. — Experiment 134. — If possible, secure the skeleton of some vertebrate animal, preferably man. Notice how the bones are fitted to each other and how the joints are arranged to allow move-

ment. Observe how carefully the brain and the spinal cord are protected, and also the thorax, which contains the heart and lungs. If a human skeleton is procured, notice the curving of the spine which enables the body to stand erect.

THE NERVOUS SYSTEM OF MAN

Notice how the nerves are distributed to all parts of the body.

We have just studied briefly some of the invertebrates most closely related to the welfare or injury of man. Man himself belongs to the other great class, vertebrates. The higher animals which furnish him with the greater part of his animal food also belong to this class. Although there are great variations in the structure of vertebrate animals, yet they are alike in having a backbone and an inner supporting skeleton.

The bony *skeleton* in the higher forms of animal life consists of a vertebral column, skull, ribs, and appendages. The main skeleton pro-

tects the most delicate organs and acts as a support for the attachment of the muscles. The appendages, like the legs and arms in man, are jointed to the central part of the skeleton, and it is the action of the muscles in moving these about the joints that makes movement from place to place possible.

In the skull is situated the great nerve center of the animal, the *brain*, and from this through the vertebral column passes the great nerve distributor, the *spinal cord*. From the brain, *nerves* are sent to all the muscles of the body, to the skin and to those organs, like the eye and the ear, which transmit to the brain impressions received from without the body. These nerves give the stimuli which cause the muscles to thicken, or contract. In fact, all the voluntary movements of animals are controlled from the brain, as the movements of trains on a railroad are controlled from the dispatcher's office.

Breathing. — All animals must have a way to breathe, or energy cannot be supplied to carry on the activities of the body. Different animals breathe in different ways, but in the higher vertebrates and in man it is the same. Breathing in man will, therefore, be taken as the type.

Air enters the body through the nose or mouth, and passes down through the windpipe into the *lungs*. In order to keep out dust and germs, the opening of the nose is supplied with a large number of hairs projecting from the mucous membrane which lines the whole nasal chamber. These hairs and the secretion from the membrane catch and hold most of the harmful particles.

It is most important that air should be breathed through the nose and not through the mouth. Air which enters

the lungs through the mouth is not sifted as it is when it passes through the nose; moreover it is not sufficiently warmed because the mouth passage is much shorter than the nasal passages. Thus the throat and lungs are irritated by mouth-breathing and are more liable to disease.

Sometimes abnormal spongy growths called *adenoids* partly fill the upper part of the throat. They not only obstruct nose breathing but also furnish a breeding place for disease germs. It is a simple matter for a surgeon to remove them; and unless they are removed, they may result in disordered stomach, quarrelsome disposition, stunted growth, and even stupidity. Most of the cases of adenoids are found in children. Children may or may not outgrow adenoids, but some or all of the evil effects remain if the trouble is long neglected. In the interest of mental and physical vigor as well as of attractiveness of countenance, the removal of adenoids ought never to be unduly postponed.

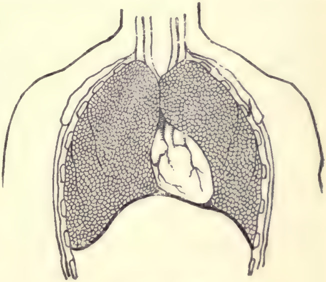
At the back of the mouth the windpipe and the throat come together.

When food is being swallowed, the passage into the windpipe must be closed, and this is done by the little valvelike *epiglottis*. If, in swallowing, the epiglottis is not able to close quickly enough, something may pass into the windpipe and cause choking. The windpipe, at the upper part of the chest, branches into two parts, one branch going to each of the lungs.

The lungs fill the upper part of the chest and infold the heart. In them the air tubes divide again and again, forming a vast network of tubes which grow smaller and smaller until they end in little air sacks. Interlacing with these air tubes are veins and arteries which carry the blood.

The tiniest parts into which the blood vessels are divided, the *capillaries*, form close networks within the linings of the air sacks. The air and blood are thus separated by an exceedingly thin animal tissue, which allows an exchange of soluble materials. Thus the blood is able to take up the oxygen needed and to rid itself of the carbon dioxide and other waste products which it has accumulated.

The air-tight thoracic cavity in which the heart and lungs are situated is inclosed and protected by the ribs and at the lower part by a dome-shaped muscle called the *diaphragm*. Air enters the lungs because the muscles of the chest pull the ribs so that they move upward and outward and the muscles of the dome-shaped diaphragm cause it to move downward. These two actions enlarge the thoracic cavity. The air enters in the same way that it enters a hollow rubber ball that has been compressed and then set free. When the ribs move downward and the diaphragm upward, the air is expelled as in the rubber ball when compressed.



THE LUNGS

They are here pulled aside to show the heart.

There are then two ways in which air can be made to enter the lungs, the "raising of the chest" and the movement of the diaphragm. In the proper kind of breathing these two movements go on together. The lungs are filled throughout and not simply at either the top or bottom.

If this is to be accomplished, the body must be free and not restricted by tight clothing about the chest or the lower part of the trunk of the body, the *abdomen*. Not only is the right kind of breathing necessary for properly supplying the blood with oxygen, but also that the lung tissues themselves may be properly nourished and cared for. We should be particularly careful about this now that infectious diseases of the lungs are so prevalent.

Circulation. — **Experiment 135.** — If a compound microscope can be procured, tie a string tightly around the end of a clean finger, and when it has become full of blood, prick it quickly with a sterilized needle. Rub the drop of blood that comes out on a glass slide and quickly examine under the microscope. Notice the great number of round, disklike bodies, red corpuscles. Try to find an irregular-shaped body which, while the blood remains fresh, slowly changes its shape, a white corpuscle. These are rather difficult to find, but can be seen if the drop of blood is thoroughly examined quickly enough.

In order that all parts of the body may be provided with the materials used in building their cells and in doing the work necessary for continued existence there must be a distributory system. This is necessary wherever diversified work is to be carried on. This necessity has brought into effect the railway and canal systems of the world. The body is a little world by itself, and it has a most complete and wonderfully adapted system for supplying the material needed and for removing the waste. The center and motive power of this system is the *heart*. The medium of circulation is the *blood*.

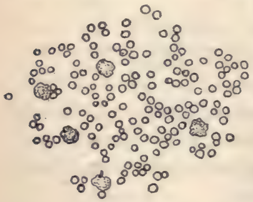


FIGURE 132

When the blood is examined, it is found to consist of a watery liquid, called the *plasma*, a great number of little disk-shaped bodies, the *red corpuscles*, and some irregular whitish bodies, the *white corpuscles* (Figure 132).

The white corpuscles are protoplasmic cells possessing the power of movement and even of working their way out of the blood vessels. They are the soldiers of defense of the human body. When a white corpuscle comes in contact with a disease germ, the body of the corpuscle takes the germ into it and tries to digest it. The germ in turn tries to multiply inside the corpuscle and to feed on it. Unless the germs increase in number too rapidly, the white corpuscles come off victorious. The blood also provides other substances that are probably even more important than white corpuscles in fighting disease. Some of these substances kill disease germs and others counteract germ poisons.

A WHITE CORPUSCLE DIGESTING A GERM (Greatly magnified.)

The main function of the red corpuscles is to carry oxygen from the lungs to the different living cells of the body. They contain a pigment, *hæmoglobin*, which carries the oxygen and gives the blood its color. The plasma, an exceedingly complex fluid, is composed largely of water, but contains the nutrient and waste materials supplied by the different organs of the body.

The blood passes through different kinds of vessels. Those leading from the heart are called *arteries*, and those returning to the heart are called *veins*. As the arteries proceed from the heart they divide continually, becoming smaller and smaller until they terminate in very small, thin-walled vessels called *capillaries*. These capillaries unite and form veins. Thus the blood is continually flow-

ing from the heart through the arteries and capillaries into the veins and back to the heart.

As a rule the arteries are below the surface of the body, where they are protected, but if the finger is placed on the wrist or the side of the face near the ear, an artery can be felt through which the blood is pulsing. The veins can be seen in the back of the hand and a pin piercing the body anywhere will break open some of the capillaries and cause blood to ooze out. The capillaries spread throughout the entire tissue of the body and supply with food and oxygen the different living cells of which the body is composed.

THE CIRCULATORY SYSTEM
Notice the veins (white) are nearer the surface than the arteries (black).

The heart is a muscular force pump composed of four chambers, two *auricles* and two *ventricles*. It is shaped somewhat like a pear and is situated almost directly behind the breastbone. The blood coming back from the veins flows into the right auricle, a chamber with rather flabby walls. From here, it passes through a valve into the right ventricle, which is a chamber with very thick

muscular walls. From the right ventricle, the blood is driven out through the arteries, capillaries, and veins of the lungs, where carbon dioxide is given off and oxygen absorbed by the red corpuscles.

Returning from the lungs, the blood enters the left auricle and when this becomes full, passes through a valve into the left ventricle. This has such powerfully muscular walls that it is able to force the blood throughout the body and back again to the right auricle. As the blood leaves either ventricle, there are valves that close and prevent its return. If the hand is placed a little to the left of the breastbone, the strong contraction of the ventricle can be felt.

CROSS SECTION OF THE HUMAN HEART

Showing auricle, ventricle, and ventricle valve.

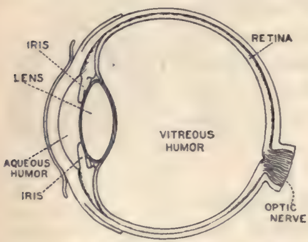
The Senses. — In order that the brain may communicate with the outside world and so be able to protect the animal from destruction and to provide for its well-being, animals are provided with a number of *sense organs* which communicate with the brain by the nerves. The most conspicuous sensations of the human body are taste, smell, touch, sight, and hearing.

On the *tongue* and in the *nose* are cells which transmit to the brain the impressions produced upon them by different qualities, the one of solutions and the other of gases. The sensations thus produced are called *taste* and *smell*.

The sensation of *touch* originates in the skin and is much more acute in some portions than in others. The tips of the fingers in the blind are often trained to such delicate perception that they, in a great degree, take the place of

the lacking sense organ. These sensations, like all others, are carried to the brain by the nerves and there interpreted into the sensation of touch.

Sight. — The organ of sight, the *eye*, is an exceedingly sensitive, automatically adjustable camera that records through the nerves. The camera box is the hard, bony socket in which the eye is placed, the *eyelid* is the shutter, and the *iris*, the diaphragm. The iris is the membrane in the front of the eye which opens or contracts to let in more or less light. In the center of it is a hole, the *pupil*.



CROSS SECTION OF THE HUMAN EYE
The pupil is the opening surrounded by the iris.

Back of the diaphragm, or iris, is a small adjustable *lens* and beyond this the sensitive plate, the *retina*. Between the iris and the front of the eye is a waterylike material, the *aqueous humor*, which keeps the front of the eye extended into its rounded form. Back of the lens is a thick, transparent, jellylike material, the *vitreous humor*, which holds the retina extended and keeps the eye from collapsing.

Instead of moving the retina back and forth to focus a picture, as is done with the ground-glass plate in a camera, the eye lens is capable of adjusting itself so as to focus objects which are at different distances. Leading back to the brain from the retina is the *optic nerve*, which carries the impressions made on the retina to the brain, where they are interpreted into the sensation of *sight*.

Moving Picture of a High Jump

This rough comparison is by no means a description of the eye, for it is a most complex and wonderful organ, vastly superior in construction to a camera. A technical description would, however, be out of place here. The impression made on the retina remains for an instant; and so if successive pictures (about twelve a second) are taken of a moving object and projected on a screen at the same rate the eye will not distinguish the intervals between the pictures and the object will appear to be in motion. This is the way in which moving pictures are produced.

Sometimes the lens is not able to focus a picture distinctly on the retina, and then it is necessary to aid the lens of the eye with artificial lenses, or glasses. Silly notions about one's personal appearance in glasses should never stand in the way of wearing glasses when they are necessary. If there is a strained feeling when the eyes are used, or if headaches result from continued use of the eyes, reliable advice should be sought.

The eye is so important for our usefulness and happiness that the greatest care should be taken of it. One should not read when he is lying on his back, when the light is either poor or glaring, or when the book cannot be held steadily. The eye may be infected from public washbowls, public towels, or even by rubbing with one's own fingers. Any infection of the eye demands skillful treatment and should not be trifled with.

FIGURE 133

Sound and Hearing. — **Experiment 136.** — Arrange a large, wide-mouthed bottle with a small bell suspended in it from the stopper and a delivery tube extending through the stopper. (Figure 133.) Attach the delivery tube by a thick-walled rubber tube to an air pump and exhaust the air from the

bottle. Shake the bottle so that the bell can be seen to ring but does not strike the sides of the bottle. Can the sound be heard distinctly?

Experiment 137. — Suspend a pith ball by a light thread so that it may swing freely. Strike a tuning fork and quickly place it in very light contact with the pith ball. The ball will be set in motion by the vibrations of the tuning fork.

In Experiment 136 it was found that if the air was exhausted and the bell did not touch the sides of the bottle, almost no sound was heard when the clapper of the bell showed that the bell was ringing. This shows that the sounds we usually hear are transmitted in some way by the aid of the air. In Experiment 137 the sounding body was seen to be vibrating. Since these vibrations set the pith ball moving, we may understand that the air surrounding the tuning fork must also have been set in motion.

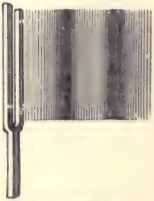


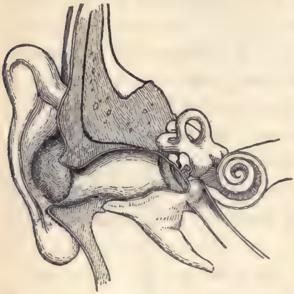
FIGURE 134

Sound has been found to be a wave motion in a material medium. If a scratch is made on the end of a long log, it can be heard if the ear is placed at the other end of the log, when it cannot be heard if the ear is away from the log. In this case the medium is the wood.

If a stone is dropped into a quiet pond, the rippling waves developed will extend often to the farthest shore of the pond, but a chip floating near where the stone fell will not be moved from its position except up and down. Thus the waves traveled outward from the point of origin, but there was no outward movement of the water. If a long rope, attached at one end and held in a horizontal position, is suddenly struck with a stick, a wave motion will travel along the

rope from end to end, but the particles of the rope will simply move up and down. It is in a similar way to this that the sound waves travel, but the particles which transmit the sound only move back and forth through small distances. (Figure 134.) An echo is simply a reflection of sound waves from some obstruction they meet.

The *ear,* which is the sound transmitter of the body, consists of the outer ear, which is so arranged as to catch the sound waves and converge them upon the ear drum. The *ear drum* is a thin membrane stretched tightly across a bony opening and vibrates when the air waves strike it, as a drum does when struck by the drumstick. On its inner side the drum is attached to the inner ear by a chain of three bones. The sensitive cells of the inner ear transmit the impressions made by the sound vibrations through the *auditory nerve* to the brain, where they are interpreted into the sensation of *sound.*



CROSS SECTION OF THE HUMAN EAR

The drum head of the ear is easily broken, and therefore no hard instrument should ever be thrust into the ear. There is an old saying that one should never pick his ear with any kind of hard instrument having a smaller point than one's elbow. Immediate and skillful attention should be given to any inflammation of the ear. If neglected it may lead to deafness or even to an exceedingly dangerous abscess in the bone back of the ear.

Food. — Experiment 138. — Chop a piece of the white of a hard-boiled egg into pieces about as large as the head of a pin and place in a test tube. Chop up another piece much finer than this and place it in a second test tube. Make a mixture of 100 cc. of water, 5 cc. of essence of pepsin, and 2 cc. of hydrochloric acid. Pour into each test tube enough of this mixture to cover the white of egg to a considerable depth. Shake thoroughly and put in a place where the temperature can be maintained at 37° C. or 98° F. A fireless cooker or a bucket of warm water is good for this. Allow to stand for several hours, keeping the temperature constant. The white of egg is dissolved, the action being more rapid in the second tube. Try the same experiment using water; using dilute hydrochloric acid. Do these have the same effect as when used with the pepsin? The pepsin solution is an artificial gastric juice.

In order that the work of the body may be carried on, food is required. This food may be supplied by either animals or plants. The original source of all animal and plant food, as has been seen, is in the chlorophyll manufactory of the leaf and green stem. After this leaf food has been manufactured, it is simply modified by the plants and animals through which it passes. The food is used (1) in growing new cells, (2) in repairing cells that have been used up or destroyed, (3) in providing energy to carry on the activities of the body and maintain its heat, or (4) in doing external work, such as moving the body itself from place to place or moving other bodies.

To furnish any of this energy, the cells must be able to combine food with oxygen. To do this the food must be digested or prepared so that it can pass through animal tissue. In the higher animals, a complicated apparatus is provided to accomplish this. In man it is briefly as follows: a long, continuous tube, the food-tract or the *alimentary canal* (Figure 135) extends through the body. Different

portions of this tube are adapted to different processes. In the mouth, the teeth grind the food into small bits and mix it with the *saliva*. This is an exceedingly important part of the process, because if the food is not ground fine, the digestive juices cannot readily get at it, and the whole process of digestion is greatly retarded. Thus much more energy is expended than otherwise would be. The saliva is necessary to digest some of the starch and to aid in the further digestion.

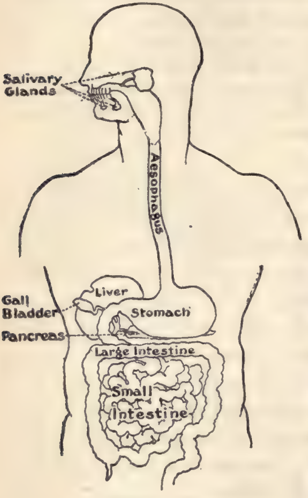


FIGURE 135

The food passes from the mouth down the throat and through an orifice to the *stomach*. This is a large pouch which will hold usually from three to four pints. It has muscular walls which enable it to contract and expand, thus keeping the food moving about so that it is thoroughly mixed with the *gastric juice*. The gastric juice is secreted by little glands thickly embedded in the lining of the stomach. Artificial gastric juice was made in Experiment 138. Some of the proteins (foods containing nitrogen) are digested in the stomach, although the larger part of digestion takes place in the small intestine.

From the stomach the food passes through a valve into the *small intestine*. This is a complexly coiled tube which

fills the larger part of the abdomen. The inner wall of the tube is lined with glands which secrete digestive juices, and into the intestine are poured the secretions from two large glands, the *pancreas* and the *liver*. The small intestine is the great digestive organ of the body. Here the fats and oils are digested, and the digestion of the starches and proteins is completed. The small intestine opens through a valve into the *large intestine*, a tube five or six feet long decreasing in size toward the exit from the body. There is little digestion in the large intestine.

The changes that take place in the food as it passes through the alimentary canal are very complex, but during its progress the valuable part of the food is so changed and prepared that it can be absorbed by the blood and transported by it to the different parts of the body where its energy is needed. Absorption takes place all along the alimentary canal wherever the food has been sufficiently prepared.

In the entire process of digestion of food the only part that can be controlled by the individual is the chewing of the food. It is necessary that the food be ground fine in order that the digestive juices may readily act upon it and not leave any undigested fragments as abiding places for germs. Decayed and unbrushed teeth furnish unlimited breeding places for germs. Careful experiments have shown that the health of the body and the mental vigor are greatly increased by properly caring for the teeth. The teeth must be kept clean and all cavities must be properly filled if health is to be maintained.

SUMMARY

Plants and animals make up the live part of the earth. Most green plants consist of root, stem, and leaves. The root

anchors the plant to the ground and takes in from the soil all the plant's food except carbon. This is supplied from the carbon dioxide of the air, which enters the plant through the leaves. Leaves are the original food manufactories for all plants and animals. Stems vary greatly in the positions they assume, but their chief functions are to support the leaves and to conduct food solutions from the root to the upper-structure of the plant. The two great classes of stems are monocotyledonous and dicotyledonous.

The stem also usually supports the flower, which consists in the main of calyx, corolla, stamen, and pistils. The chief function of the flower is to produce the seeds from which succeeding generations of plants grow. The enlarged tip of the stamen is called the anther. This produces pollen grains. When a pollen grain of the right sort falls on the head of the pistil, called the stigma, it fertilizes an egg cell in the ovary, which is at the base of the pistil, thus producing the embryo of a new plant, which is the living part of a seed. Pollen grains are carried and spread by the wind and by insects and birds. The seeds are also scattered by the wind, by animals, and by flowing streams.

Besides these green plants which prepare their own foods, there is another great group of plants that may be called dependent. Instead of preparing their own food by the help of the sun, they live upon food that has been prepared by green plants.

Among the familiar dependent plants are mushrooms and toadstools. Bacteria and yeasts are single-celled dependent plants. A bacterium reproduces by dividing in two. A yeast reproduces by budding. Molds are dependent plants which are made up of many cells and which reproduce by spores.

Animals take their energy indirectly from the foods prepared by green plants or by other animals. They are usually classed as invertebrate and vertebrate. The lowest form of invertebrate is the protozoön. Worms and insects are other forms of invertebrates, the importance of which is seldom realized.

The bony skeleton in the higher forms of vertebrates consists of a backbone, skull, ribs, and appendages. In the skull is the brain, connected with the various parts of the body by nerves. Vertebrates breathe by receiving air through the windpipe into the lungs. This is done by the muscles of the chest and the diaphragm. The lungs purify the blood, which circulates from the heart through the arteries and capillaries and returns through the veins.

The five senses are taste, smell, touch, sight, and hearing. These sensations are carried to the brain by the nerves, which come from the nose, the mouth, the skin, the eye, and the ear, respectively. Sound is a wave motion in a material medium. The ear is a sound transmitter, which conveys sound vibrations by way of the auditory nerve to the brain.

For all the activities of body and brain food is required. As the food passes through the alimentary canal, various juices are mixed with it and certain parts of it are digested and absorbed into the circulatory system of the body.

Questions

What are the three parts into which many plants can be readily separated?

In what three respects are plants and animals alike?

Of what use to the plant are the roots? Why are roots necessary to the higher plants?

Describe some different kinds of stems that you have seen and explain their adaptability or lack of adaptability for making the best of the conditions where they were.

What do the leaves do for the plant? How do they do it?

What is the value to the plant of the flower? How are the flowers prepared to carry out their part in the life struggle of the plant?

Describe any way in which you know that animals have been of assistance to plants.

How do plants provide for the dispersal of their seeds?

How does the seed develop into a plant?

With what useful or what harmful chlorophyll-lacking plants have you ever had experience?

Name and describe some of the invertebrate animals you know.

What is the general structure of the worm?

What insects have you known that are beneficial? What that are harmful?

What is the use to the vertebrate of the skeleton and the nervous system?

Describe how vertebrate animals breathe. Why is it vitally necessary for them to breathe freely?

What is the use of the blood? How does it get around to where it is needed?

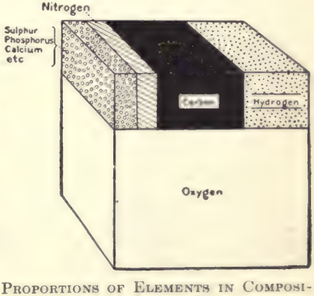
Describe the ways in which man becomes aware of what is outside his body.

Why is food needed? How and where is it digested?

CHAPTER XIV

MAN'S EXISTENCE AS RELATED TO PLANT AND ANIMAL LIFE. FOODS.

Fundamental Foods. — The elements which enter into the structure of the human body, such as oxygen, hydrogen, nitrogen, carbon, etc., are comparatively few and are abundant in the world about us, either separately or in compounds. But with all of man's ingenuity, he has never learned to manufacture these elements into compounds that will serve as food for the human body.



Proportions of Elements in Composition of Living Things

The leaves of plants are the fundamental food factories of the world. Here carbon, hydrogen, and oxygen are united by the aid of the sun into plant foods called *carbohydrates*. *Fats* and *proteins* are two other kinds of foods that are also manufactured in the bodies of both plants and animals, but the carbohydrates are the *original* material out of which the living organism, whether plant or animal, *first* produces fats and proteins.

Air, water, and salt are necessary to the processes of life,

but they are not generally classed as foods. In leaves then and in leaves only are the lifeless (inorganic) substances of the earth combined into substances that will support life (organic compounds). The factories of nature are open to man, and he knows fairly well what these factories produce. But how the compounds are produced either in the plant or in the animal and how the active material of the living cells called protoplasm does its work are mysteries to him. By careful study, however, man has learned a great deal as to foods necessary to the growth and health of the human body.

Necessary Foods. — **Experiment 139.** — Place in different test tubes small amounts of (1) corn starch, (2) grape sugar, (3) scrapings from a raw potato, (4) flour, and (5) the white of an egg. Pour in a little water and shake thoroughly. Drop into each tube a few drops of the iodine solution prepared in Experiment 120.

Experiment 140. — Place in test tubes small quantities of (1) the white of a hard-boiled egg, (2) tallow or lard, (3) grape sugar, and (4) any other food which may be handy. Pour a little concentrated nitric acid into each tube and allow to stand for a minute. Be careful not to get the nitric acid on the clothes or hands. Pour the acid out into a slop jar and wash the substances with a little water. Pour off the wash water and pour on a little strong ammonia. If the substances turn a yellow or orange color, proteins are present. Which substances contain proteins?

Experiment 141. — Gasoline vapor is very inflammable; be sure in this experiment that there is no flame in the room. Place about a spoonful of (1) both the white and the yellow of an egg, (2) flaxseed meal, (3) yellow corn meal, (4) white flour, and (5) other foods it is desired to test in separate evaporating dishes or beakers near an open window. Pour on these more than enough gasoline to cover them, and stir thoroughly. Cover the evaporating dishes and allow to stand for ten or fifteen minutes. Pour the gasoline off into a beaker and set the beaker outside the window until the gasoline has evaporated. If there is anything left it

must have been dissolved from the food. If a substance remains, place a drop of it on a piece of paper. Smell of it. Try to mix it with water. Rub it between the fingers. Try any other fat or oil test of which you can think.

Experiment 142. — In a place where there is a good draft so that odors will not penetrate the room, burn in an iron spoon over a Bunsen burner (1) small pieces of meat, (2) a little condensed milk or milk powder, (3) part of an egg, and (4) any other food. Is there a residue left after burning? If so, this is mineral matter.

A Date Palm

In the preceding experiments we have dealt with the three great groups of organic compounds, carbohydrates (starches and sugars), fats and oils, and proteins (foods containing nitrogen). The foods that contain large percentages of carbohydrates are vegetables, fruits, and most cereals. The fats are most abundant in butter, cream, fat meats, nuts, chocolate, and vegetable oils such as olive and cottonseed oils. The common foods that are rich in proteins are lean meats, eggs, beans, peas, and certain cereals, especially oatmeal. Milk contains all three of these compounds in approximately the proportions needed by the body.

Careful experiment has shown that the average, full-grown American needs each day two to three ounces of proteins, about four ounces of fats, and a pound of carbohydrates. The weight of food eaten, however, is very much greater than this, as all foods are composed largely of water, and contain other substances which the body throws off as waste. The proteins are needed for growth and repair, since the living part of the cells, the protoplasm, is composed of proteins.

A Bunch of Dates
An excellent food for hot climates.

All foods furnish energy when they are oxidized in the body. Until recently it was thought that a great deal of meat was necessary to furnish the energy required for hard muscular work. But investigation has shown that this energy can better be supplied by carbohydrates and fats. When carbohydrates and fats are oxidized in the body to produce energy, the waste is largely water and carbon dioxide, which the body readily throws off. But when for lack of carbohydrates the body is compelled to oxidize proteins to produce energy, certain nitrogen wastes are produced which the body does not throw off so easily. Continued strain of throwing off these poisonous wastes in

large amounts may lead to serious disease. The widespread custom in America of eating meat three times a day is not only expensive but also unhealthful. A small amount of meat once a day is all that even a hard-working man needs.

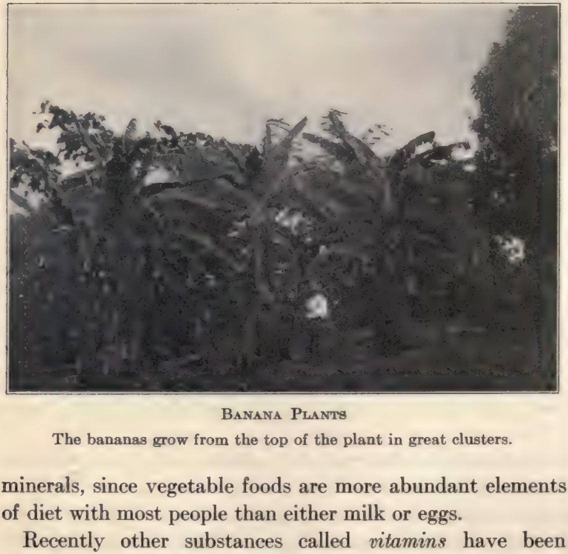
Where men live in cold regions or are much exposed to cold, the body requires great energy to keep up its heat.

SUGAR CANE CUTTING

Fats are the substances that oxidize most readily in the human body, and these are needed in great abundance by men who have to withstand exposure to cold. "Fats are fuels for fighters" was a slogan of literal truth which the United States Food Commission used on its posters during the World War. The body readily converts sugars into energy, and so sugars are also a valuable cold weather food. The staple food of northern Africa is the date, which is

admirable for hot climates because it is practically a complete food with a minimum of fats.

Mineral matter such as iron for the red corpuscles, lime for the bones and teeth, and phosphorus for the protoplasm must also be included in our food. Eggs furnish all three of these; milk is rich in lime; but vegetables and the *outer layers of grains* contain the main supplies of these



BANANA PLANTS

The bananas grow from the top of the plant in great clusters.

minerals, since vegetable foods are more abundant elements of diet with most people than either milk or eggs.

Recently other substances called *vitamins* have been found necessary to the maintenance of a healthy body. They are found in fresh (not salt) meats, fresh milk, raw vegetables and fruits, and in the outer layers of grains. Since heat drives off these vitamins, we must rely mainly

upon raw fruits and raw vegetables for our supply of these substances. Even the slight heat necessary to pasteurize milk drives off the vitamins.

A study of the few facts that have been presented here will indicate that vegetables and fruit should form a much larger proportion of the American diet than they now do. Men who live almost exclusively on white bread and meat are starving their bodies for certain very necessary substances, and are overworking their systems to throw off poisonous wastes. When the Food Commission asked during the World War that we eat less meat and more of the dark breads containing the outer layers, or brans, of the cereals, they were asking us to do *ourselves* as well as our soldiers and the Allied peoples a favor.

Besides the necessary foods, most individuals desire especial additions for relishes and beverages. These commonly consist of spices, tea and coffee, and other like materials. When used in moderation, they are usually harmless. But they should be avoided by children and not used to excess by adults.

Alcohol, except possibly in exceedingly small quantities, cannot be considered a food, and as a stimulator for the appetite it should not be used. Many careful experiments have shown that while it may stimulate the body temporarily, it does not enable it to do more work. Instead, those using it cannot do as much work, or withstand as great physical or mental strain, as those not using it.

Even if it were not for the ungovernable appetite which its use almost invariably engenders, and for the degrading influences with which its use is usually surrounded, its physiological action is such as to lessen the body's vitality, decrease its resistance to disease, and dull its nervous and

mental efficiency. So surely do deteriorating results follow its steady use that insurance companies regard men who use alcohol as bad risks. Railroads and many great industries refuse to employ users of alcohol.

Coffee Plant
Showing the clusters of beans from which coffee is produced.

Whatever scientists may conclude as to the food value of minute quantities of alcohol, they agree that as a steady "stimulating" beverage, it must be classed as a poison.

Careful scientific experiments have also been made upon the effect of tobacco. Although there are differences of

opinion about its effect upon fully matured adults, there is no such difference of opinion in regard to its effect upon those who have not stopped growing and are not yet fully matured.

Measurements and comparisons made in regard to the physical development, endurance, and mental ability of a large number of college men have shown conclusively that those who have not used tobacco, as a rule, have better physiques, are better students, and can stand more physical exercise than those who have used it. In the competition for athletic teams it is found that only about half as many of those who have used tobacco make good, as of those who have not used it.

Preparation of Foods. — When foods are appetizing, look good, smell good, and taste good, both the saliva and the gastric juice are secreted in larger quantities, so that this sort of food, when taken into the system, is more readily digested than food which is not attractive. One of the reasons for cooking food is to render it appetizing, and this should never be lost sight of by the cook. Cooking also softens and loosens the fibers of meats and causes the cell walls of the starch granules to burst, thus rendering it possible for the digestive juices to attack the food more readily. In addition, cooking kills the germs and other parasites that are sometimes found in foods.

To cook food properly is a fine art and requires most careful study and great skill. The science of providing economically the kinds of food necessary and of cooking these properly so that they will be attractive, easily digested and will lose none of their nutritive value, is one that is at present in its infancy. Human beings, like other animals,

Ancient Cooking Utensils

must have a balanced ration or diet if they are to be most productive economically. They differ from other animals in having a much greater range of food possibilities and in being much more sensitive as to the appearance and taste of food.

One Day's Balanced Ration for Five Persons

Plants That Change Food. — If it were not for microscopic plants (page 398), food would keep indefinitely without change. These little plants are, however, present everywhere and if conditions are suitable for their growth they begin at once to change or to "spoil" all foods they can reach. Some of the bacterial changes make food more

Bread Mold. (Greatly magnified.)

palatable, for it is bacteria that give the fine flavors to the best butter and cheeses and the gamy flavor to certain kinds of meat. Bacteria also change cider into vinegar.

Experiment 143 (Teacher's Experiment). — Make a solution of molasses and water. Place some yeast in it and put the mixture away in a warm place. Watch it for a few days, and after gas bubbles have been coming off for some time put the solution in a flask connected with a distilling apparatus, as shown in Figure 136. Gently heat the solution and collect the distillate. Smell of the distillate. What does it smell like? Dip a piece of cotton cloth in it and touch a lighted match to it. If the experiment has been successful, the distillate will burn. If not, distill some of the distillate again. Alcohol and carbon dioxide are produced by the action of the yeast on the molasses and the alcohol is evaporated by low heat and condensed in the still.

The ancient Egyptians knew that if flour was mixed with water and left in a warm place it would soon become porous; and that if pieces of this porous dough were put into

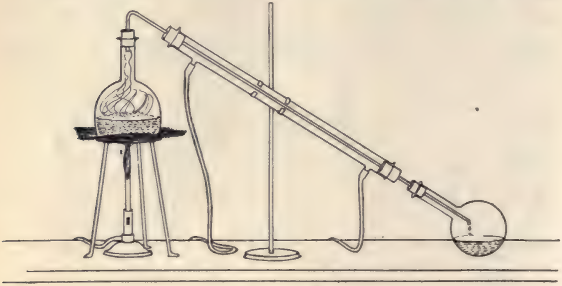
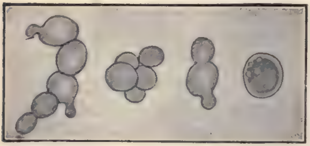


FIGURE 136

other dough, they would make this dough become porous more quickly. These pieces of dough were called leaven, and the leavened bread of the ancients was made in this way. Even to-day in some countries this method is followed. The Romans sometimes used a leaven made out of grape juice and millet. In these methods, the wild yeast plants which exist almost everywhere in the air found a favorable lodging in the prepared substance, and by their growth and activities "raised" the bread. Later, methods were devised for cultivating the yeast plants, and the making of "raised" bread became common.



YEAST PLANTS

In modern bread making, yeast, which contains the minute yeast plants, is mixed thoroughly into the material which is to compose the bread; and the bread is then put into a warm place to rise — or, more exactly, to allow the yeast plants to multiply. If the materials and the temperature are right, the yeast plants multiply very rapidly, feeding upon the material of the dough, and changing sugar into carbon dioxide and alcohol. Little bubbles of carbon dioxide gas are developed throughout the dough, making it slightly porous.

The dough is then kneaded to develop the elasticity of the gluten and to mix the greatly increased number of yeast

BREAD MAKING IN MEXICO

plants uniformly through the mass. It is then set aside again so that the uniformly scattered yeast plants may continue their activities. Bubbles of carbon dioxide form throughout the whole mass, and a light spongy dough results. When this is heated in the oven, the tiny bubbles of gas expand, making a more porous sponge, the alcohol evaporates, and the dough bakes, thus forming light bread.

Sometimes other substances besides yeast are used to generate the carbon dioxide necessary to raise the dough. In Experiment 26, it was found that the action of an acid on certain substances liberated carbon dioxide. Often in making biscuits and cake, soda and sour milk are used. The gas is liberated by the action of the acid in the sour milk upon the baking soda. Baking powder, which usually consists of baking soda and cream of tartar mixed with corn-starch, is also used. When the baking powder is mixed with flour and moistened, the cream of tartar acts like an acid upon the soda, liberating carbon dioxide and thus causing the dough to rise. As in bread, the gas is expanded by the heat of the oven, making the cake or the biscuits more porous.

Most of the minute plants which cause changes in food render it unfit for man's use. We have found that decay, which is caused by bacteria, is on the whole a friendly process. But we look upon it as an unfriendly process when it results in the souring of milk, the tainting of meat, the spoiling of eggs, and the rotting of vegetables — all of which are due to the activities of bacteria.

The decay in fruit, the mold on bread, the corn smut, the smut on oats and barley, the potato blight, the scabs of apples and potatoes, the rusts on grains, and many other common plant diseases are simply fungous plant growths. The wheat rust alone costs the United States many millions of dollars each year. Thousands of feet of timber are destroyed yearly by the wood-destroying fungi. Dry rot of timber, as it is called, is due to a fungous growth. The fight against these harmful fungi costs millions of dollars each year.

Experiment 144. — Place a slice of freshly boiled potato in each of six clean, 4-ounce, wide-mouthed bottles. Close the mouths of

the bottles with loose wads of absorbent cotton. Place five of these bottles in a sterilizer and sterilize for half an hour. Allow the sixth bottle to remain unsterilized. (A sterilizer can be made by taking a covered tin pail and putting into the bottom of it a bent piece of tin with holes punched in it to act as a shelf on which to put the bottles. A shallow tin dish with holes in it is good for the shelf. There must be holes so that the steam will not get under the shelf and upset it. Fill the sterilizer with water to the top of the shelf and place the bottles on the shelf. Keep the water boiling.) A reliable, inexpensive sterilizer is the pressure cooker shown on page 126.

Take the bottles out and allow them to cool. Remove the cotton from one of them for several minutes and then replace. Run a hat pin two or three times through the flame of a Bunsen burner to sterilize it and place it in the water of a vase which has had flowers in it for some time. Carefully pulling aside the edge of the absorbent-cotton stopper in the second bottle, insert the pin and place a drop of the vase water on the surface of the piece of potato. After having sterilized the pin again, rub it several times over the moistened palm of the hand and then, using the same precautions as before, scratch the potato in the third bottle. Put a fly in the fourth bottle, using the same precautions. Keep the fifth bottle just as it was taken from the sterilizer as an indicator, that is, to see whether the bottles were thoroughly sterilized. Put all of the bottles away in a warm place and observe them each day for several days. The spots appearing on the pieces of potato are bacteria colonies.

Since bacteria and fungi cause the "spoiling" of food, and since certain bacteria develop poisons called ptomaines which make the eating of the food infected very dangerous, it is necessary that food be protected as far as possible from bacteria and that their growth be checked. Food should never be handled except with clean hands; it should be most carefully protected from dust and flies and kept in a clean, cool place. Most bacteria do not thrive where it is cold.

Preserving Food. — When it is desired to preserve food for a long time, especial care must be taken. It has been found that thoroughly drying food will protect it against bacteria; that freezing or smoking fish and meat preserves them; that salt and vinegar and spices act as preservatives; that if fruits and vegetables are heated for some time at a boiling temperature and tightly sealed in cans they will keep; that fruits do not spoil if placed in strong sugar sirups; that fruits and vegetables and eggs can be kept without spoiling where the temperature is maintained at a little above the freezing point.

PREPARING SMOKED FISH AT GLOUCESTER

In all these cases the bacteria in the food are either entirely destroyed and the food is absolutely protected from other bacteria, or else the growth of the bacteria is completely checked. Sometimes eggs are preserved for a considerable time by placing them in a waterglass solution. In this case the waterglass fills up the tiny pores in the shell of the egg and keeps out the bacteria just as paint keeps them out of wood. In the case of the egg, however, there is plenty of moisture within the egg for the growth of whatever bacteria may be present, whereas in painted dry wood the moisture is kept out and the bacteria are unable to grow.

In order to keep bacteria from spoiling meat, borax is sometimes used. Formalin is sometimes put into milk to keep it from souring, and benzoate of soda into catsups

Courtesy of Beech-Nut Packing Co.

STERILIZING CATSUP AND CHILI SAUCE

The metal baskets filled with bottles of chili sauce and catsup are lowered into the sterilizing tanks, which are constructed on the principle of the pressure cooker (page 126). Notice the abundant lighting and scrupulous cleanliness of the room.

for the same reason. These three substances act as preservatives, but *they also make the food unwholesome* and so we have pure food laws prohibiting the use of such preservatives for foods.

Bacterial Diseases. — Out of the fifteen hundred or more kinds of bacteria that are known, only about seventy may grow in our bodies and make us ill. Most of the others are

man's efficient helpers. These disease-causing bacteria, however, may cause a vast amount of trouble. The microscopic plants and animals that cause disease are commonly called *germs*.

Almost all disease germs get into the body through a break in the skin or through the mouth or nose. The skin when unbroken is a splendid germ armor. When it is broken the bacteria have a chance to enter. In the majority of cases there are not enough hostile bacteria at hand to make serious trouble; but there is always a chance of their being present, and so all wounds ought to be cleansed, disinfected and dressed with absorbent cotton, or some similar substance. We found in Experiment 144 that absorbent cotton kept the bactéria out. If wounds are not given careful attention, blood-poisoning, which is a bacterial disease, may set in. Sometimes when a rusty nail or other dirty substance breaks through the skin, bacteria are carried into the flesh. If such a wound is not properly disinfected and cared for, lockjaw, another bacterial disease, may be developed.

First Aid Kit

By getting into the body through the mouth or nose, bacteria cause many other diseases. Among these are influenza (grippe), diphtheria, pneumonia, whooping-cough, typhoid fever, and tuberculosis. People having diseases of these kinds throw off a great number of bacteria. If such germs get into the bodies of other people, they may cause the same diseases there. Disease germs usually do not

float in the air for any great distance from the diseased person. But danger lurks in handling articles infected by germs, from eating infected food, or from drinking infected water.

All dishes and utensils used by persons having contagious or infectious diseases should be kept by themselves, washed in boiling water, and not used by other people. All their bedding and clothing should be thoroughly washed in some disinfectant, boiled if possible, and hung for some time in direct sunlight. Rooms should be disinfected before they are used by other persons. In very contagious diseases mattresses and materials which cannot be disinfected should be burned. As all germ diseases are spread by sick people, epidemics can be prevented if sufficient care is taken.

So closely are people brought together in our towns and cities that carelessness on the part of one may endanger many, and it is particularly necessary that regulations be enforced which shall protect society from the careless spreading of disease. In some very virulent diseases, such as smallpox or diphtheria, the patients ought to be kept to themselves, quarantined, their rooms and everything about them disinfected, and every precaution taken to prevent people susceptible to the diseases from being exposed to the germs.

This cannot and ought not to be done in all cases of bacterial disease, since adequate protection can be given if sufficient care is taken by the person affected. If tubercular patients will carefully cover their mouths with cloths when coughing or sneezing and see that the cloths are burned, tubercular germs will cease to be a menace to society. Although thousands are afflicted each year with tuberculosis, largely through the carelessness of those having it, the disease is readily preventable and curable. If the same precautions

are taken in whooping cough or grippe, or ordinary "cold," the infection will not be spread.

As we said before, the fight put up by the white corpuscles is not the only fight the body makes against bacteria and their activities. When disease bacteria get established in the system, they secrete a poison called *toxin*, which is absorbed by the blood and carried throughout the body, thus poisoning many other parts beside those immediately attacked by the bacteria. The cells of the body at once begin to secrete a substance to counteract this poison, an *antitoxin*. If the vitality of the patient is great enough, sufficient antitoxin will be secreted to neutralize the effect of the toxin and the disease will be overcome.

Of late years it has been found that these antitoxins can be artificially supplied or caused to develop. Thus the system may be aided in neutralizing the effect of the toxin, and in warding off the disease. By injecting these antitoxins or stimulating their development, people are now protected against smallpox, diphtheria, and other diseases. So carefully are these preparations made at present that if proper care is taken in their injection, there is almost never any ill effect from their use.

How to Disinfect. — Most bacteria thrive best at a moderate temperature (70° to 95° F.). Almost all of them are killed if kept at a boiling temperature for a short time. They cannot grow where there is no moisture, and all but a few kinds are killed by complete drying. Direct sunlight is soon fatal to them.

For disinfecting wounds, iodine or a dilute solution of carbolic acid or lysol serves well. (These must not be taken internally.) Hydrogen peroxide is a good external cleanser

and has some disinfecting qualities. Cinders may often be washed out of the eye and the eye disinfected with a dilute solution of boracic acid. Strong disinfectants should never be used in the eyes or nose. A solution of listerine is a safe mouth wash.

For disinfecting sinks or washbowls a generous quantity of boiling water containing a small amount of carbolic acid or lysol is very effective. Chloride of lime is the most common disinfectant for sewage pipes leading from bathrooms. Woodwork and wall fixtures may be wiped with a dilute solution of carbolic acid or formalin. It must be remembered that some of these household disinfectants are deadly poisons if taken internally.

FIGURE 137

Rooms are disinfected by burning sulphur in them. The sulphur gas will not be effective, however, unless the atmosphere of the room is very moist. Moisture can be supplied to the atmosphere by thoroughly spraying the room with a fine atomizer or by boiling water in it for some time. Formaldehyde candles (Figure 137) are also burned in rooms to disinfect them. These have proved quite satisfactory. Soap and water, sunlight and air, are the only disinfectants needed for rooms except in case of contagious or infectious diseases.

Dangers from Infected Food and Water. — If foods are handled by diseased persons or by those whose dirty hands have acquired disease bacteria, or if the foods are allowed to stand exposed to dust and dirt, they collect germs. If the food is afterward thoroughly cooked, the germs are gener-

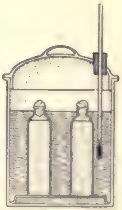
ally killed. If, however, as in the case of bread, fruit, and some vegetables, no cooking is done before the foods are eaten, the foods may often carry disease.

Milk is particularly liable to be infected with disease germs because they readily grow in it and increase rapidly. Many epidemics of typhoid fever, scarlet fever, diphtheria, and other germ diseases have been directly traced to polluted milk. Either the milk came directly from dairies where these diseases existed, or had been put into bottles taken from infected homes and not afterward sterilized. The older such milk becomes the greater is the danger of using it since bacteria multiply in it with such tremendous rapidity.

Milk Delivery in Belgium

Infants are particularly liable to contract diseases from impure milk because this is their main diet. Statistics show that a large percentage of infant deaths are caused by infected milk. If milk is scalded the germs are killed, but scalding makes milk less palatable and less digestible. When milk is thoroughly heated to a temperature of 160° F. for fifteen or twenty minutes, the disease germs are

killed but the milk itself is not made less digestible nor is its taste affected. This is called *pasteurization.* The milk should be cooled quickly after it is heated, covered with absorbent cotton, and kept in a refrigerator so that fresh germs cannot infect it. Pasteurized milk is the only safe milk to use unless it is absolutely known that great care has been taken to keep the milk at all times clean and cold enough to be safe from infection. Certain cities require that all milk sold shall either come from healthy cows in dairies of "certified" cleanliness or else shall be pasteurized. Refrigerators and places where milk and food are kept must be washed and thoroughly scalded with hot water frequently if they are to be kept free from bacterial infection.

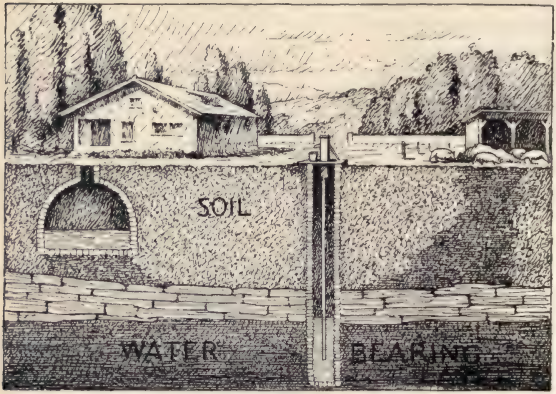


A SIMPLE PASTEURIZING OUTFIT

Water is also a dangerous carrier of bacteria. Water from deep artesian wells is usually safe, but streams that flow over the surface of the ground continually have washed into them materials which contain germs. Unless great care is taken to keep surface water out of springs or wells and to keep the drainage from stables and outbuildings from seeping into them, they become dangerous as sources of water supply. Impure water is an ever active source of disease and one that cannot be too carefully watched.

Many of our large cities have in recent years expended vast sums of money upon their water supplies in order that citizens may be protected as far as possible from disease. The drainage canal which Chicago built at great expense to divert its sewage from Lake Michigan greatly lowered the death rate from typhoid fever in that city. Further de-

crease in typhoid and intestinal diseases in Chicago is due to the fact that a large part of the milk which is now used there is pasteurized. Care concerning these two most important supplies, water and milk, has greatly decreased the death rate in many American cities during the present century. It is estimated that the actual money loss each year in the



A WELL WITH CONTAMINATED WATER SUPPLY

United States because of the ravages of preventable diseases is between one and two billion dollars.

When there is any doubt about the purity of water it should be boiled. This will kill the dangerous bacteria. Ordinary house filters are useless and often worse than useless, as they simply become breeding places for bacteria. They may make the water look clearer but they do not destroy the bacteria; and it is the bacteria, not the solid matter, that constitute the real danger.

Bacteria can live and grow in such minute cracks that to use dishes washed in impure water is about as dangerous as to drink the water. All public towels and drinking cups should be abolished. Experiments have shown that even drinking fountains unless most carefully constructed are liable to retain in the pipes germs left by other users. The use of the individual cup is the one safe method for drinking.

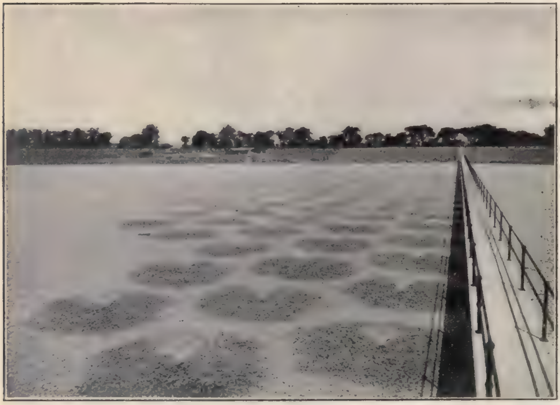
Paper Drinking Cup

Sewage Disposal. — The proper disposal of human waste is a vital problem. Exposure to wind and flies allows the germs in it to be spread about. The waste must therefore be disposed of in some way or disinfected. On the farm or in small towns where

Courtesy of Department of Public Works, Columbus, Ohio

Sewage Disposal Bed, Solids

running water can be supplied, cesspools and septic tanks answer the purpose. In cities, however, most complicated systems of sewage disposal must be employed. In the most healthful cities the sewage is gathered from all parts of the city by means of water flowing in underground sewers. In seaboard cities the sewers usually empty into the sea and the tides and currents dispose of the sewage.



Courtesy of Department of Public Works, Columbus, Ohio

SEWAGE DISPOSAL, LIQUIDS

Cities upon large rivers frequently empty their sewage into the rivers, but this pollutes the water far downstream. A very much better way than this has of late years been devised and is being used by many inland cities. Sewage disposal plants are built, where the sewage is run into large tanks and the solid matter is decomposed by the action of certain kinds of bacteria. The liquid is then slowly

filtered through beds of sand and gravel, and the sewage is thus freed of organic impurities.

Cleanliness. — Every year we are learning more and more about disease. The World War has demonstrated in a wonderful manner the advances which have been made in

A Primitive Washing Scene in Mexico

life saving as well as in life destruction. Diseases like smallpox, typhoid fever, and bubonic plague, which were formerly dreaded so greatly by armies, have been practically eradicated. Wounds which only a few years ago were always fatal are now easily healed. All of this has come about because of our increased knowledge of disease germs and how to combat them.

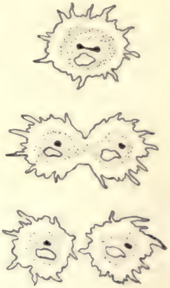
Prominent, however, above everything else stands out the fact that cleanliness is the great protector of health. Those communities that have well-built sewers, clean streets, clean milk, and clean water are healthy. The community through its boards of health must protect the individual from the germs of contagious and infectious diseases, for he cannot do this by himself. Persons that eat pure food, drink pure water, breathe pure air, and keep their bodies pure are usually healthy.

The Americans were able to build the Panama Canal because they were able to protect the workmen from disease germs. Disease had defeated previous attempts. They were able to make Havana, Cuba, a healthy and healthful city — although for years it had been one of the plague spots of the world — by cleaning it up and destroying the breeding places of disease germs.

A Disease-bearing Mosquito
The mosquito is greatly magnified.

Animal Life that Causes or Spreads Disease. — Certain low forms of animal life, the protozoa, have already been mentioned as disease producers. Unlike bacteria, the protozoa do not cause disease by passing directly from one person to another. Instead, they need to live in some insect between whiles. In malaria and yellow fever the insect in which they live is the mosquito, and in the sleeping sickness they live in a fly called the *tsetse*. If a mosquito of

the right species bites a person afflicted with malaria or yellow fever, some of these little animals, the protozoa, are sucked up with the blood and enter the mosquito. They grow in its body, undergoing several changes, until the animal germs are ready to be injected into their victim, when they pass into the salivary glands of the mosquito. In biting, the mosquito always injects a little saliva into the wound and with this go the germs. These enter the blood, multiply rapidly, and cause the disease.



AMŒBA DIVIDING

If mosquitoes can be kept from biting people who have these diseases or if infected mosquitoes can be kept from biting other people, such diseases will not spread. The best way to keep

A "MALARIAL" SWAMP

A breeding place for mosquitoes.

mosquitoes from biting is to exterminate them. Since mosquitoes breed in stagnant water, all old ditches or small pools where water accumulates should be emptied and drained. Larger stagnant pools should be drained or have a film of kerosene spread over their surface by frequently pouring a little of the oil on the water. This will keep the mosquitoes from breeding and prevent the diseases.

The Texas fever, which has caused such great financial losses to the cattlemen of the United States, is caused by a protozoan injected into the cattle by the bite of a tick.

Bubonic plague, the "Black Death" that swept Europe during the Middle Ages, is spread by the bite of a flea that lives on plague-infested rats. Hundreds of thousands of dollars have been spent by the Government in killing rats in some of the ports of the United States where the plague has succeeded in landing. Many seaports are now rat-proofing their wharves in an effort to exterminate these pests. The cables holding ships to the docks are often passed through holes in the centers of metal sheets in order to prevent rats from entering a ship by walking along the cables. Sailors have learned that if the rats are kept out, the plague is kept out.

House Fly (Magnified)

Flies. — The words *fly* and *filth* are almost synonymous. Flies breed in any kind of decaying vegetable or animal matter. The eggs hatch in about a day and the little white maggots after absorbing filth for about ten days change into adult flies with their

hairy bodies and sticky feet, especially adapted for carrying all kinds of germs and for spreading them over everything they touch. The fly delights to feed on all kinds of foul or diseased objects, and the waste it deposits is often full of dangerous germs.

"Swat the fly" is indeed a proper slogan. But a still better plan would be to destroy all filth or to dispose of it so as to prevent flies from breeding. Flies never travel far and their presence indicates filth in the neighborhood. If manure and other decaying matter is kept in covered pits until it is used for fertilizing, and if garbage cans are kept covered, much more will be done to exterminate the fly than by swatting. Houses should be carefully screened and all food kept covered from these carriers of disease, but along with all precautions to avoid the fly must go consistent efforts to exterminate the fly.

BACTERIA COLONIES
These were developed from the tracks of a fly on a gelatine plate.

Health Hints. — Good health is man's greatest asset. If he is to attain his highest power he must maintain his health. His muscles must be exercised so as to stimulate the cells to grow and to throw off their waste products. The skin must be frequently bathed so as to remove the dirt and waste materials that clog the pores. The body must have sufficient rest and sleep so that the cells will not be worn out faster than they can be reproduced.

One must have plenty of food but not too much, or the stomach and other organs will suffer from overwork. The

use of stimulants, such as tobacco, alcohol, and all other harmful drugs must be avoided since all of these interfere with the proper growth, development, and work of the various cells of the body. The cure-all patent medicines, which do not cure at all but which simply dope the sensibilities of the individual, should be shunned as poison. Fresh air and sunshine are the best and surest preventives of disease; and when these are combined with proper rest, food, clothing, exercise, and bodily cleanliness, there is little danger of sickness except from highly contagious diseases.

Every day each person probably receives into his system thousands of disease germs. Usually it is only when the vitality of the body is low that these germs are able to establish themselves. Right living is the great disease preventer.

SUMMARY

The elements which enter into the composition of the human body, such as hydrogen, oxygen, nitrogen, carbon, etc., are comparatively few and are abundant in the world about us. As foods they are found in three classes of compounds, carbohydrates, fats, and proteins. All foods furnish energy when they are oxidized in the human body. Proteins are especially needed for growth and repair of tissues; but since it is easier for the body to throw off wastes from oxidized carbohydrates and fats, these should constitute the largest part of our energy-producing diet. Men exposed to cold need sugar and fats in greater abundance than those who live much indoors or in warm climates. Foods containing iron, phosphorus, lime, and vitamins are also essential in the diet of all persons. Spices, tea, and coffee should be used in moderation by adults and avoided by

children. Tobacco is positively harmful to immature persons, and alcohol as a beverage or common stimulant must be classed as a poison. Proper cooking renders most food both more palatable and more digestible.

Microscopic dependent plants cause changes in food. The yeast plant is employed in bread making; certain bacteria change cider to vinegar; and others are responsible for the fine flavors of the best butter, cheeses, and certain kinds of meat. Still other bacteria cause foods to spoil. To preserve food against such bacteria, we dry it, freeze it, smoke it, boil it, and seal it in air-tight receptacles; or employ sugar, salt, spices, or vinegar as preservatives.

Some bacteria enter the body and cause diseases. This explains why we disinfect wounds, quarantine persons suffering from infectious diseases, and cleanse thoroughly or destroy all household articles with which such people come in contact. The body fights disease germs by means of the white corpuscles of the blood and by means of antitoxin secreted by the cells of the body. Every household should be supplied with certain common disinfectants; and every household and community should guard against infected food and water, and attend to the proper disposal of waste and sewage. One of the most effective means of combating or preventing disease is to maintain cleanliness.

Flies are great carriers of disease bacteria, and certain kinds of mosquitoes, fleas, and other insects cause diseases by injecting disease-producing protozoa into the blood of victims.

Exercise, bathing, nutritious food, proper clothing, fresh air, sunshine, sufficient rest and sleep, avoidance of harmful stimulants and drugs, shunning of cure-all patent medicines, and cheerfulness are among the essentials to health.

Questions

What are the three great groups into which foods are divided?

Why are fruits and vegetables so necessary?

Why should not alcohol and tobacco be used?

What are the advantages derived from proper cooking?

What is the value of yeast in bread making? Describe and give reasons for the process usually employed in bread making.

Why are some bacteria and other minute plants so harmful?

How can food be preserved and kept wholesome?

What should one do to protect himself from bacterial diseases?

How should milk and water be cared for? Why?

Why is cleanliness so essential to health?

Why should people take especial care to protect themselves from mosquitoes and flies?

CHAPTER XV

MAN'S INVENTIONS FOR TRANSFERRING AND TRANSFORMING ENERGY

Tools. — Primitive man early found that it was to his advantage to use something besides his own hands and feet to apply his energy. Probably the first tool that he used was a stone which he threw at some animal he wished to kill for food. Soon he found that if he put the stone in a strip of hide and swung it around his head, he could send it with greater force. Thus he invented the sling, probably the first device for transferring energy and the first war machine.

MAN'S FIRST WAR MACHINE

Since then he has not only invented many machines that have enabled him to exert his own physical energy to greater advantage, but he has also devised machines which make it possible for him to use the energy that exists in the world about him. This ability to utilize the energy of nature has made the life of modern man very different from that of his savage ancestors. Without machines there could be no large cities, no manufacturing,

U. S. Official

HAND GRENADE THROWING

The utilization of hand throwing in modern warfare.

no transportation facilities, none of the conveniences that make modern life comfortable.

More and more man is relying upon machines driven by nature's energy to do the work he has heretofore done by his own physical exertion. The mowing-machine, the sewing-machine, and the automobile are recent examples of such inventions. All these intricate devices, however, have a few simple machines as

U. S. Official

BATTLE "TANK"

A modern complex war machine.

SPINNING WHEEL

A most useful application of simple machines. Spinning is now done by much more complex machinery.

their basis. These basic machines are the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw.

Friction. — If we attempt to slide a box along a level floor, we find that we have to overcome resistance or *do*

work. If we put rollers under the box there is *less* resistance, but *some* resistance always develops when two surfaces are moved over each other. This resistance is called *friction*. The rougher the two surfaces, the more the friction; and the smoother they are, the less the friction.

INDIAN WEAVING

A form of skilled manual labor which modern machinery has almost done away with.

To lessen friction we make surfaces that slide over each other very smoothly and oil them. Rolling surfaces are found to have less friction than flat surfaces, and so we use ball or cylinder bearings in bicycles, automobiles, and many other machines. But no matter what we do, some of the work exerted on a machine is always used up in overcoming friction. In an efficient machine the friction is reduced in every possible way in order to avoid as far as possible "loss of energy." In some of the simple machines, especially the wedge and the screw, friction is always so great that the machines are not very efficient.

The Lever. — **Experiment 145.** — (*a*) Bore a small hole through a meter-stick at each of the decimeter divisions. Place on the table

a small board so that its edge shall be even with the edge of the table. Weight or clamp the board to the table. Into the edge of the board drive a round-finish, small-headed nail so that it will

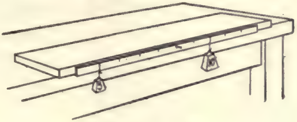


FIGURE 138

project horizontally over the edge of the table. Slip the nail through the center hole of the meter stick. (Figure 138.)

Hang a weight of 400 g. from the first decimeter hole. Find out how much weight will be required at each of several holes on the other side of the nail in order to balance the 400 g. weight. In each case, multiply the weight on each side of the nail by its distance from the nail and compare the results. Lift one end of the meter-stick 10 cm. above the edge of the table, and note how far each weight moves. Multiply each weight by the distance it moved up or down, and compare the results.

FAMILIAR APPLICATIONS OF THE LEVER

(*b*) Attach a small spring balance by a short string to one of the end holes of the meter-stick. Slip the nail through the hole next to it. Hang a weight of 400 g. from any one of the other holes. Pull down on the spring balance until the meter-stick is in a horizontal position. Note the pull on the spring balance and make the same computations as in (*a*). Repeat the experiment and computations by hanging the weight from several different holes.

(Exact accuracy in these experiments would require a consideration of the weight of the meter-stick itself, but for the purposes of this experiment, results will be nearly enough accurate without this.)

The lever was probably one of the first machines used by primitive man. He pried up rocks and pried open logs to get the roots and small animals he needed. It was to him simply a convenient way of using a stick. But when Archimedes, the greatest mathematician of ancient times, worked out the principle of this simple machine, he was so much impressed with the mechanical advantage to be derived from its use that he said, "Give me a fulcrum on which to rest and I will move the earth."

GRINDING CORN, SCOTCH HIGHLANDS
A simple application of the lever.

He found, as was indicated in Experiment 145, that the longer the power arm is than the weight arm, the greater is the weight a given force can lift, but the smaller the distance it can lift it. If the experiment could have been accurately conducted, it would also have proved that the power multiplied by the distance the power moves is equal to the weight multiplied by the distance the weight moves.

THE LEVER AS USED BY THE ROMANS FOR WEIGHING

These scales were dug up at Pompeii and are about 2000 years old.

Careful experiment has shown that this last statement is true for all machines, and so it is sometimes called the law of machines. It can be stated in another way: What is gained in power is lost in speed and what is gained in speed is lost in power. Notice the machines you are familiar with and observe how this law holds good. All of us are using different kinds of levers every day. Balances, scissors, nutcrackers, wheelbarrows, forceps, and the treadle of a sewing-machine are all examples of levers.

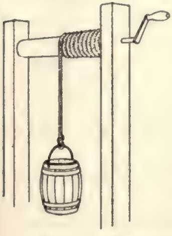


FIGURE 139

Wheel and Axle. — The windlass used to lift water out of a well and the capstan of a boat are the most familiar examples of this form of machine. (Figure 139.) The wheel and axle is simply a modification of the lever. (Figure 140.) The power travels through the distance of the circumference of one

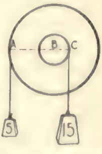


FIGURE 140

wheel (A) while the weight travels through the distance of the circumference of the other wheel, or axle (C). If the circumference of the power wheel is three times the circumference of the weight wheel, a force of 5 pounds exerted on the power wheel will lift a weight of 15 pounds on the weight wheel.

FIGURE 141

FIGURE 142

FIGURE 143

The Pulley. — **Experiment 146.** — (*a*) After well oiling some small pulleys arrange one of them as in Figure 141, having a weight of about 500 g. on one end of the cord and a spring balance on the other. Slowly pull down on the spring balance and note the reading on the scale. Allow the balance to rise and note the reading. Friction accounts for the difference between the first and the second reading of the scale. Average the two readings and see how nearly the average equals the weight on the other end of the cord. May we say that the force exerted by the hand is equal to the weight? Does the hand move through the same distance as the weight?

(*b*) Arrange the pulleys as in Figure 142. Allow the balance to descend, noting the force recorded on the scale. Pull up on the balance, noting again the reading on the scale. Find the average between the two forces, which may be called the true force. Is the force now exerted by the hand equal to the weight? If not, what are the relations of these two forces?

FIGURE 144

Note the distance moved by the hand and also the distance moved by the weight. How do they compare?

(*c*) Arrange the pulleys as in Figure 143. Make determinations similar to those in (*a*) and (*b*). How does the force exerted by the hand now compare with the weight? How does the distance moved by the hand compare with that moved by the weight?

It is sometimes exceedingly convenient to change the direction of a force even if no other advantage is gained. To do this, a rope may be passed over a wheel, and thus one may by pulling down lift up the weight. Such an arrangement is called a fixed pulley. (Figure 141.) The cord

COMBINATION OF PULLEYS USED TO LIFT HEAVY BURDEN

Because of the mechanical advantage of the pulleys, relatively small power is needed to lift this electromagnet, with tons of scrap iron clinging to it.

in passing around the wheel simply has its direction changed, but there is no gain for the user of the machine either in power or in distance.

If now the pulley is arranged as in Figure 142, it is no longer a fixed pulley but is movable. It is evident in this case that the weight is supported not by a single cord as in the fixed pulley but by two cords, the part of the cord at-

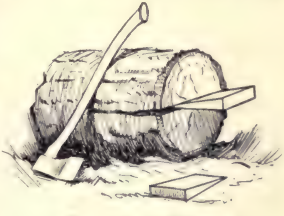
INCLINED RAILWAY, SWITZERLAND
A gigantic inclined plane.

tached to the beam and the part of the cord held by the hand. The hand will need to move twice as far as the weight is lifted.

A number of pulleys may be arranged as in Figure 143 so that the movable pulley with the weight attached is supported by several cords. In this case each section of the cord supporting the movable pulley sustains its proportion of the weight, and the power is as many times less than the weight as there are cords supporting the movable pulley. But the gain in power means a loss in distance. The power will have to travel as many times farther than the weight as there are cords supporting the movable pulley. An arrangement like this enables a small power slowly to lift a large weight.

The Inclined Plane. — When the ancient Egyptians built the great pyramids, it was necessary for them to raise huge

blocks of stone to great heights. It would have been next to impossible for them to do this simply by using brute force. Some simple machine was necessary. They probably used the same kind of machine that is used to-day in rolling a barrel into a wagon or in grading wagon roads or railroads over mountain passes — an inclined plane. The more gradual the inclination up which the weight travels, the smaller the power required to lift the weight. Again, what is gained in power is sacrificed in distance.


USE OF THE WEDGE

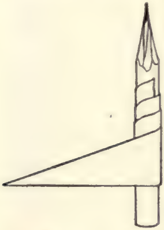


FIGURE 145

The Wedge. — The wedge consists simply of two inclined planes placed back to back. It is principally used in forcing substances apart, as when wedges are used to split wood and stones, or as needles and pins are used in pushing apart the fibers of cloth. Axes and chisels and most cutting tools except saws act on the principle of the wedge.

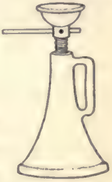


FIGURE 146

The Screw. — The screw is simply an inclined plane ascending around a central axis. (Figure 145.) The projection of the plane from the axis is called the thread. The plane moves the distance between the threads in making one turn around the axis. A spiral staircase is a machine

of this kind. The screw is another example of a gain in power with a corresponding loss in distance. The screw, generally combined with the lever, is used in many ordinary machines. The jackscrew (Figure 146), copy-press, and vise are examples of combinations of these two simple machines.

Man's Most Important Energy Transformers. — Perhaps the first of nature's forces that man made use of was the wind. He hoisted a sail for the wind to strike upon and to push him from place to place. In about the twelfth century A.D. he discovered a way of arranging sails upon a wheel, thus constructing a windmill to help him in his work. The windmill is still used in some places where small power is needed, but the wind is no longer one of man's main sources of energy.

AN ANCIENT SAILBOAT

Running water early impressed man with its power. He finally harnessed this power for grinding his grain and for doing other kinds of work by means of the water wheel. Many shapes of wheels were tried before the mighty turbine, such as is used at Niagara Falls, was invented. It is probable that more power is now developed at these Falls than was developed by all the earlier water wheels ever used.

About the middle of the eighteenth century, a young Scotchman, James Watt, invented a machine to utilize the

power of expanding steam. He arranged a cylinder containing a piston so that the steam would be admitted alternately on one side and then on the other side of the piston. As the expanding steam forces the piston in one direction, the used steam in front of the advancing piston escapes through an open valve. When the piston reaches the end

A Simple Water Wheel Used for Grinding Corn

of its stroke, the moving valves cut off the steam from the one side and allow it to enter the other, thus driving the piston back again and forcing the used steam out through the escape. This continuous back and forth movement of the piston can best be understood by an examination of the accompanying diagram. (Figure 147.)

In recent years inventors have made it possible to apply

steam under great pressure to a wheel somewhat similar in construction to a water turbine. Thus steam is made to give a rotary motion, instead of the back and forth motion of the ordinary steam engine, which must be converted into rotary motion by the connecting rod and crank. These steam turbines, as they are called, have been used to great advantage in ocean vessels where there is little space available for machinery and where great power and high speed are desired.

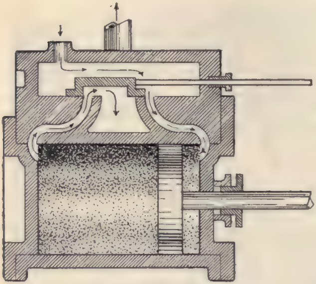


FIGURE 147

In the gas engine the energy of gas exploding in a cylinder behind a piston takes the place of expanding steam in driving the piston. Usually two or more cylinders are used, and the explosions are so timed that a very steady motion is given to the shaft. These engines were first made about fifty years ago but have been greatly improved recently, and are now used very extensively for automobiles, motorboats, and airplanes.

The electric dynamo and the electric motor, which will be discussed later, are other energy transformers which man has developed and now constantly uses.

Power Available to Man. — When combustion is used as a source of energy, man is drawing upon his bank account with nature, and is using up the stored energy of the earth. But in utilizing the energy of blowing wind and running

water, he is conserving energy that would otherwise be wasted. "The mill can never grind again with water that is past." There is, however, only so much water power in the country and it is exceedingly important that these

ELECTRIC POWER PLANT AT NIAGARA

Conserving the energy of running water by transforming it into usable electrical energy.

sources of power should remain in the possession of all the people as represented by their Government and not be monopolized for the commercial gain of a few people. In recent years the United States Government has arranged to retain control of power sites on public land, and to lease rather than sell water power to individuals and corporations. Running water is a never-stopping, sun-power engine, and its use should be the birthright of mankind.

SUMMARY

Man has invented many simple and complex machines for transferring and transforming energy, and has thus simplified the doing of work. Among the machines which are used simply or in complex combinations are the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw. He has invented complex machines for transforming the energy of running water, of burning fuel, and expanding steam, and of exploding gases into forms of energy that may be utilized at will. The natural sources of power should never be monopolized for the commercial gain of a few people; they should remain the birthright of mankind.

Questions

Which of the six basic machines have you used? What machines have you seen that combined several of these basic machines? Explain how they were combined.

In what ways have you ever observed energy transformed by machines so as to do useful work?

What forces of Nature have you ever seen used for man's advantage? How?

CHAPTER XVI

TWO RELATED FORCES MAN HAS HARNESSED — MAGNETISM AND ELECTRICITY

Magnetism. — So much were some of the ancients impressed with the property of loadstones (page 37) for attracting iron that one of them suggested building a great arch of this material in a temple so that the iron statue of the goddess would remain suspended in the air without resting upon any support. There is an old legend that the iron coffin of Mahomet rose and remained near the ceiling of the mosque in which it was buried.

Experiment 147. — Touch with each end of a bar magnet small pieces of paper, copper, zinc, iron, sawdust, and any other materials that may be handy. Which substances are attracted by the magnet? Does it make any difference which end is used? Take a knife blade that has no such attractive power and rub it several times along one end of the magnet; then touch the different substances with it. Has it acquired any new power?

FIGURE 148

Experiment 148. — Suspend a bar magnet horizontally in a sling made from a bent piece of wire (Figure 148). Bring one of the ends of another bar magnet toward it. What is the effect? Reverse the ends of the magnet; is there any change in the position of the suspended magnet? Bring a large, soft iron nail toward either end of the suspended magnet. What is the effect? Reverse the ends of the nail. (Be careful that the nail has not become permanently affected by the magnet.) Is the effect the same as when the ends of the magnet were reversed?

Bring pieces of copper, zinc, and other substances toward the magnet. Do these affect it? Notice that the ends of the bar magnet are marked. What can you state about the attraction or repulsion of similar ends of magnets? Of opposite ends? Does it make any difference in its effect on the suspended magnet toward which end the nail is brought? What substances do you find attracted by the magnet?

To the end of a small nail hanging by attraction to a magnet bring another nail. How does the first nail act in respect to the second?

Experiment 149. — Suspend by a string a short bar magnet in a sling, as in Experiment 148. Turn it around in several different directions. After each change allow it to come to rest in whatever position it will. Does it prefer any one position to all others?

It was early discovered that when pieces of steel were rubbed on a loadstone they took on the properties of the loadstone and became *magnets*. In the experiments with magnets, it was found that like poles repelled and unlike poles attracted, and that iron or steel in contact with a magnet becomes magnetized. Iron and steel are practically the only substances attracted by a magnet, although nickel and cobalt and a few other substances have a little attraction. Thus steel and iron are always used for magnets.

The Magnetic Field of Force. — **Experiment 150.** — Place a plate of window glass about 8×10 inches above a bar magnet and carefully sprinkle iron filings over it. Describe the behavior of the filings. Sketch on a piece of paper their arrangement. Move a small compass about above the glass plate and note the directions the needle assumes. How do the actions of the needle and of the filings compare? If feasible make a blue print of the filings.

Holding the small compass two or three inches above the magnet move it parallel with the magnet from end to end. Gently tap the compass occasionally so that the needle will move freely. How does

the needle act when it is over the ends of the magnet? How does the direction of the compass needle compare with the direction of the bar magnet?

In the experiment just performed we found that when iron filings were sprinkled above the magnet they arranged themselves in definite lines. The small compass needle also arranged itself along these lines when brought under the influence of the magnet. There is, then, around a magnet a magnetic *field of force* which affects magnets and magnetic substances brought within it. It is found that magnetic intensity, like the intensity of sound and light, varies inversely as the square of the distance.

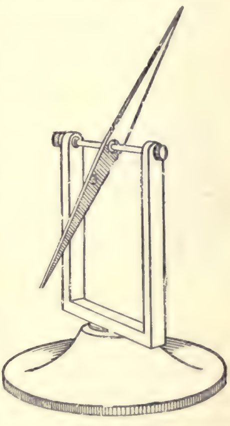


FIGURE 149

When the compass was placed above the ends of the bar magnet one of the ends of the needle was pulled down toward the magnet, or it might be said to *dip* toward the magnet. When moved near the middle of the magnet it assumed a horizontal position, and when it approached the opposite end of the magnet the opposite end of the needle dipped. This same action is found when a magnetic needle is carried from north to south upon the earth. If a needle is carefully balanced and then magnetized, it will be found no longer to assume a horizontal position.

In the northern hemisphere the north end will dip and in the southern hemisphere the south end. In the northern

hemisphere it is customary to make the south end of the needle a little heavier so that it will stay in a horizontal position. At the magnetic pole the needle would stand vertical. If a needle is accurately balanced on a horizontal axis and then magnetized, it will show the angle of dip in any locality. Such a needle is called a *dipping needle* (Figure 149).

The Mariner's Compass. — In the ordinary mariner's compass (Figure 150) a magnetic needle is arranged so that it will swing freely in a horizontal plane. A circular card is divided into four equal parts, the dividing lines of which are marked with the cardinal points of the compass, the intervening spaces being divided into eight equal divisions. The card is attached to the needle and inclosed in a box called the *binnacle*. This box is arranged so that it will always remain horizontal. A fixed line on the binnacle shows the direction of the keel of the ship. The card being attached to the needle always has its "north" pointing toward the north. To determine the direction of the ship it is only necessary to notice on the card in what direction the keel line is pointing. The mariner of course must know the declination at the place where he is and make the proper corrections. The different governments furnish tables and charts showing these corrections.

FIGURE 150

Theory of Magnetism. — **Experiment 151.** — Heat a No. 20 knitting needle red hot and plunge it quickly into cold water. This tempers the needle so that it will break readily. Magnetize the needle as was done in Experiment 8. When it has become well magnetized, break it in the middle. Test each half with a sus-

pended magnet, as was done in Experiment 148. Is each half a full magnet or only half a magnet? Break these halves again and test. What effect does breaking a magnet have upon the magnet?

In Experiment 151 it was found that if a magnet is broken in two, each half is a perfect magnet. If these halves are broken, each piece is a perfect magnet, and so on as long as the division is kept up. It is also found that if a magnet is heated or suddenly jarred or pounded it loses its magnetism. If a magnet is filed into filings and these filings are put into a glass tube, the tube will have no magnetic properties but will act to a magnet like an ordinary iron bar.

FIGURE 151

If now the tube is held vertically and tapped several times on a strong magnet, the tube will be found to have acquired the properties of a magnet. The tapping joggled the particles so that they could arrange themselves under the influence of the magnetic pole and when they became so arranged a magnet was the result. If the filings are now poured out of the tube and then put back again, there will be no magnetization.

It was the arrangement of the tiny magnetized particles which must have caused the contents of the tube to become magnetic. It would therefore seem probable that magnetism must be a property of the exceedingly small particles or *molecules* of which the iron or steel as well as all other substances are supposed to be composed.

It is supposed that when a bar of steel becomes magnetized the molecules arrange themselves in definite directions, as do the filings in the tube. The molecules of magnetic substances are supposed to be separate little magnets. In the unmagnetized bar (Figure 151) their poles point in all

directions, dependent upon their mutual attraction; and thus they neutralize one another. When the bar becomes magnetized the molecules tend to arrange themselves so that like poles lie in the same direction (Figure 152). When the magnet is heated or jarred the molecules are moved out of this alignment and the magnetism is weakened.

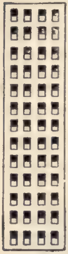


FIGURE 152

Electricity by Friction. — It was known by the ancient Greeks that when certain substances, one of which was amber, were rubbed, they had the power of attracting light objects. This property was afterward called *electricity*, from the Greek word for *amber*.

Experiment 152. — Place some small pieces of paper or pith balls on a table and after rubbing a glass rod with silk bring it near the pieces. Do the same with a stick of sealing wax or a hard rubber rod rubbed with flannel or a cat's skin. Note the action of the pieces.

Experiment 153. — Rub a glass rod briskly with silk and place in a wire sling such as was used in Experiment 148. Bring toward one end of the glass rod another glass rod which has been rubbed with silk. Do the rods attract or repel each other? Bring toward the suspended rod a piece of sealing wax or a vulcanite rod which has been rubbed with flannel or a cat's skin. Does this repel or attract the glass rod?

Experiment 154. — Suspend a pith ball by a silk thread from the ring of a ringstand. Rub a glass rod with a piece of silk and bring it near the pith ball but do not allow the two to touch. Note the action of the ball. Touch the pith ball with the rod. Does it behave now as it did before? Rub a vulcanite rod with a piece of flannel or cat's skin and bring it near a suspended pith ball. Does the pith ball act as it did with the glass rod? Touch the pith ball with the rod. How does it act? Bring a glass rod rubbed with silk near a pith ball which has been in contact with a vulcanite rod

after it was rubbed with flannel or a cat's skin. Does the glass rod repel or attract the ball?

Experiment 155. — Suspend a pith ball from the ring of a ring-stand by a very fine piece of copper wire no larger than a thread. Wrap the wire around the pith ball in several directions. Bring a rubbed glass rod toward the pith ball. Does it act as it did when suspended by silk? Allow the ball to touch the rod. Does the ball now act as it did when suspended by silk? Try these same experiments, using the vulcanite rod.

From the previous experiments it has been seen that when glass is rubbed with silk, and vulcanite with flannel

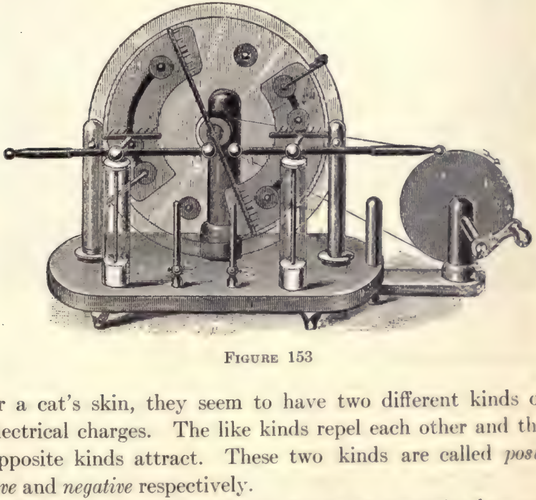


FIGURE 153

or a cat's skin, they seem to have two different kinds of electrical charges. The like kinds repel each other and the opposite kinds attract. These two kinds are called *positive* and *negative* respectively.

Whether there are really two kinds of electricity has not yet been fully determined, but electricity acts exactly as it would if there were two kinds, and it has become customary

to speak as if there were. In Experiment 154 it was found that pith balls suspended by a silk thread could be charged with electricity if brought in contact with a charged body. Experiment 155 showed that this was not possible when they were suspended by a copper wire. The wire conducted the electricity away. Substances like copper that conduct electricity are called *conductors*, and those substances like silk which will not conduct it, *non-conductors*.

A Flash of Lightning

Experiment 156. — Having started the electrical action in a static electrical machine (Figure 153), pull the knobs as far apart as the spark will jump and notice the course taken by the spark. Does it travel in a straight line? Hold a piece of cardboard between the knobs so that its edge is just within the line joining them. What effect does the cardboard have upon the direction taken by the spark? Place the cardboard so that it entirely covers one of the knobs. Is the spark able to pass through the card? Attach a wire with a sharp point to each of the knobs and extend it vertically two or three inches above the knob. Start the machine. Do sparks

now jump across between the knobs? Why are houses provided with lightning rods?

About the middle of the eighteenth century, Benjamin Franklin proved by his notable kite experiment that lightning was simply an electrical discharge between the clouds and the earth, or between different clouds. This discharge is similar to that which takes place on an electrical machine. The electricity in the clouds attracts as close as possible the opposite kind of electricity on the earth's surface and tends to hold it accumulated on high objects. If the attraction is sufficient, the electricity discharges between the cloud and the object, and we say the object was *struck by lightning*.

A Tree Completely Shattered by a Stroke of Lightning

If a sharp point, such as a lightning rod, is present on the object where the electricity tends to accumulate, it allows the electricity to pass off gradually before enough accumulates to cause damage. Lightning rods, however, must be continuous conductors and properly terminated in the ground.

Serviceable Electrical Energy. — In Experiments 152 to 156, muscular energy was transformed into electrical energy. In none of these cases, however, could the electrical energy have been made of practical service to man. Methods of producing electrical energy under different conditions had to be found before this form of energy could be made to do work. Within recent years man has done this and has thus added electricity to the forms of energy he is able to control for his service.

Current Electricity. — In Experiment 155 it was found that it was impossible to charge the pith ball when it was suspended by the copper wire. The electricity passed off, was conducted away, through the wire. We had here a current of electricity through the wire, but it was only for an instant. At the opening of the nineteenth century, an Italian by the name of Volta discovered how a *continuous* electric current could be produced. If a strip of zinc and a strip of copper or carbon are placed in dilute sulphuric acid and connected with a wire (Figure 154), a current of electricity will flow through the wire from the copper or carbon to the zinc. The current is due to the chemical action of the sulphuric acid on the zinc. Chemical energy has been transformed into electrical energy.

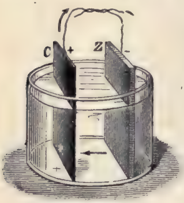


FIGURE 154

An arrangement such as that shown in Figure 154 is called a *voltaic cell,* after its discoverer. In a cell of this kind, hydrogen bubbles formed by the action of the acid on the zinc (see Experiment 56) soon collect on the copper strip, and the current weakens and finally stops. The cell is

then said to be *polarized*. If cells are to be of practical value, they must not quickly polarize; that is, a way must be found to get rid of the hydrogen bubbles. This is generally done by putting some substance into the cell that will unite with the hydrogen and thus keep the copper strip free of hydrogen bubbles. Many kinds of cells have been invented which do not readily polarize.

The so-called dry cell (Figure 155) is most used at the present time. It consists of a zinc can lined on the inside with porous paper. In the center is a carbon rod. Packed around the carbon and filling the can is usually a moist mixture of sal ammoniac, manganese dioxide, granulated carbon, plaster of Paris, and generally small quantities of other materials. In this cell the sal ammoniac acts upon the zinc somewhat as the sulphuric acid did in the simple cell first mentioned, and the manganese dioxide unites chemically with the hydrogen bubbles and thus removes them from the carbon rod. The plaster of Paris keeps the cell in rigid shape and the granulated carbon helps to keep the contents porous so that action may go on freely within the cell.

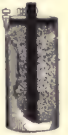


FIGURE 155

In voltaic cells the copper or carbon strip is called the *positive electrode* or *pole*, and the zinc is called the *negative electrode* or *pole*.

Experiment 157. — Connect a positive and a negative pole of two dry cells by a fairly heavy copper wire. Attach a similar piece of wire to each of the other poles and connect these pieces by means of a short, very fine, iron wire. (Figure 156.) The iron wire will become red hot. Now remove the fine iron wire and connect the loose ends of the copper wires to the socket of a small one or two candle power electric light, such as is often used to illuminate the

speedometer of an automobile. (Figure 157.) The light is made to glow.

In the preceding experiment we found that electrical energy, in overcoming the resistance of the iron wire, was changed into heat. When a current of electricity passes through any substance, the substance offers resistance to it. The amount of resistance offered by a conductor varies with the kind of material, its length and its thickness. Heating due to resistance of an electric current is utilized in the construction of electric flatirons, toasters, stoves, and other devices. The electricity is generally conducted to the utensils through a wire made up of a number of small copper wires, covered with non-conducting materials. The resistance of the connecting cord is very low.

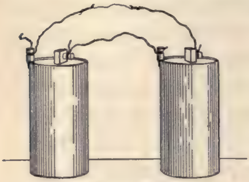


FIGURE 156

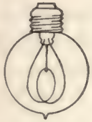
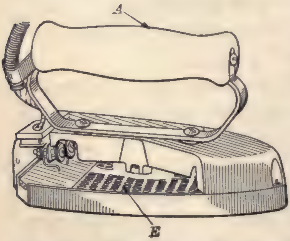


FIGURE 157

From this cord, the current passes through coils in the utensil that offer high resistance. These are so arranged that the resulting heat is delivered with almost no loss to the surface which is to be heated. Although it costs more to produce the same amount of heat by electricity than it does by the other methods usually employed in the home, yet for many purposes this heat can be applied with so



ELECTRIC IRON SHOWING HEATING ELEMENT (*E*)

little loss that the use of electricity in some kinds of heating becomes not only convenient but also really economical.

Heat generated by electricity is also used for welding (Figure 158), and is beginning to replace the forge. If metal rods are pressed together end to end and a sufficiently great current of electricity is sent through them, the heat generated at the point of contact, where the resistance is greatest, will be sufficient to weld them together. The rails of car tracks are often welded together in this way.

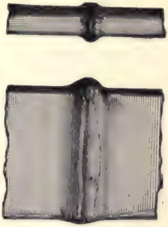


FIGURE 158

Wherever electricity is received from wires in which the strength of the current may vary considerably from time to time, it is necessary to protect electrical appliances from the heat caused by too great a current. This is done by inserting in the circuit a wire which will melt if too much current passes through it, and will thus instantly break the circuit. Such a safety device is called a *fuse*. (Figure 159.)

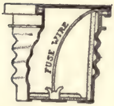


FIGURE 159

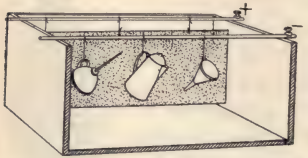
Electric Lighting. — The little electric lamp used in Experiment 157, like most other incandescent lamps, consists of a thread or filament of carbon inclosed in a glass bulb from which the air has been exhausted. When this lamp is connected with an electric current the carbon is heated white hot by the resistance it offers to the electric current. The carbon cannot burn because there is no air in the bulb, and it does not melt since there is not sufficient heat to accomplish this. Incandescent

TUNGSTEN LAMP

lamps are also made with metal filaments. Only two metals, tantalum and tungsten, have been found that will withstand the intense heat. Incandescent lamp filaments made from these metals are necessarily much longer and thinner than the carbon filaments, and are therefore more easily broken. But their great advantage lies in the fact that they use only about one third the amount of current in giving the same light. A tungsten filament will withstand much heavier jarring when it is hot than when cold.

It sometimes happens that a lamp has imperfections that render it dangerous to handle carelessly. If one touches the metal part of such a lamp when it is in use, especially with wet hands, one is likely to receive a severe shock. These shocks have sometimes proved fatal. To avoid such possible danger one should touch only the hard-rubber switch in turning a light on or off. Especial care should be taken when the hands are wet, because moisture is an excellent conductor of an electrical current.

Electroplating. — **Experiment 158.** — Almost fill a dish with a strong solution of copper sulphate (blue vitriol). Across the dish and a little distance apart, place two parallel wooden rods. Carefully clean with fine sandpaper a strip of lead and a strip of copper. Punch a hole in an end of each strip and attach to each strip two or three feet of fairly heavy copper wire. Pinch the wires firmly on to the copper and lead at the points of connection. Suspend a strip from each of the rods by winding the wire once around the rod. Attach the wire from the copper to the positive pole of a battery and the wire from the lead to the negative pole. A copper plate will be deposited on the lead.



SIMPLE APPARATUS FOR ELECTROPLATING

In the preceding experiment the copper solution is decomposed by the electric current as it passes through the solution from the copper strip to the lead strip, and the copper freed from the compound is deposited on the lead. Just as fast as copper from the solution is deposited on the lead strip, the same amount of copper is dissolved from the copper strip; and so the strength of the solution is maintained as long as there is any of the copper strip remaining. If it were desired to plate with silver, a silver strip would have to be substituted for the copper strip and a solution of a suitable silver compound substituted for the copper sulphate solution. Whatever the metal used for plating, corresponding solutions would have to be used. All gold, silver, nickel, and other plating is done in this way.

AN ELECTROTYPE

Photograph of the plate from which page 15 of this book is printed.

This book, like all books made in large numbers, has

been printed from electrotype plates. First a page was set up in type, and then a careful impression of it was taken in wax. Wax is not a good conductor of electricity and so the face of the wax mold was evenly and thinly coated with graphite in order to make it conduct electricity. The graphite-covered mold was then attached to the negative electric pole, as was the lead in Experiment 158, and immersed in the copper sulphate solution. To the positive pole was attached a copper strip. As soon as a layer of copper of the thickness of a calling-card had been deposited on the mold, taking its shape, the newly formed copper plate was separated from the wax impression and was "backed up" with type metal to make it strong enough to be used in the printing press.

Electromagnet. — **Experiment 159.** — Wind several feet of No. 20 insulated copper wire around the nail used in Experiment 148 as you would wind thread on a spool. Attach the ends of this wire to the poles of a dry cell. Bring the nail thus arranged toward a suspended magnet. Reverse the ends of the nail. Does the nail act as it did before it was placed within the coil of wire connected to the battery? Bring another nail in contact with its ends. What happens? What has the nail as arranged become? Disconnect one of the wires from the battery and try the test again. Does the nail act as it did when the battery was connected?

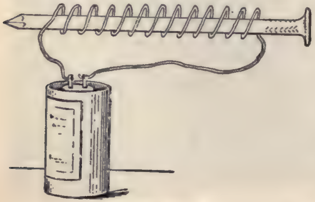


FIGURE 160

We found that if a nail is placed in a coil of wire connected with an electric battery (Figure 160) it becomes magnetic, but only as long as the connection is maintained. Magnets

of this kind are called *electromagnets*. If the nail had been hard steel and the battery exceedingly strong, the steel would have remained a magnet after being taken out of the coil.

Electromagnets have come to be of almost inestimable use in modern life. The telegraph, the telephone, the magnetic crane, the electric motor, and almost innumerable

Courtesy of Illinois Central Railroad

Electromagnetic Crane

Loading steel rails on a freight car. The magnet is lifting seven rails, a burden of about three and one half tons of steel.

other mechanical devices are dependent largely upon the principle of electromagnetism for their usefulness.

The Electric Bell. — One of the simplest applications of the electromagnet is the electric bell (Figure 161). When the punch-button (P) is pushed down it closes the circuit through the electromagnet (M). The hammer (H) is then

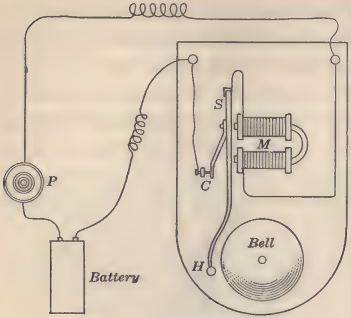


FIGURE 161. — ELECTRIC BELL

attracted toward the magnet, and as it moves toward it the circuit is broken at (C). Because of this break the current no longer flows through (M) and the soft iron cores instantly lose their magnetic power. Since the hammer is no longer attracted to (M), it is thrown back by the spring (S) to its original position, thus closing the circuit again and reëstablishing magnetic attraction at (M). This alternate closing and breaking of the circuit at (C) goes on so rapidly that the successive taps of the clapper on the bell blur into an almost continuous sound. As soon as the button (P) is released, the circuit is broken at that point and the bell ceases ringing.

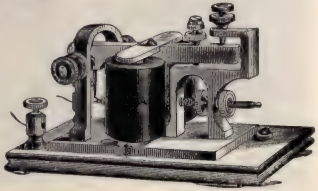


FIGURE 162

FIGURE 163

The Electric Telegraph. — In 1832 an American, Samuel F. B. Morse, invented the commercial telegraph. This was the first step in the wonderful progress that has been made during the last century

in communicating rapidly between distant points. The necessary instruments used in this form of communication are a *sounder* (Figure 162) and a *key* (Figure 163). The following experiment illustrates the arrangement and operation of a simple telegraph.

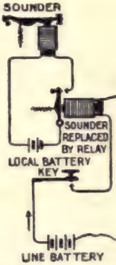


FIGURE 164

Electrical Communication. — **Experiment 160.** — Attach one end of a wire to a pole of a dry cell and the other end to one of the binding posts of a telegraphic sounder. From the other binding post of the sounder lead a wire to a binding post of a telegraphic key. Connect the free binding post of the key with the free pole of the battery (Figure 164). When the key is pushed down, the circuit is closed and the sounder clicks. If a relay can be procured, remove the sounder and connect two of the binding posts of the relay in the same way that the sounder was connected.

Connect one of the free binding posts of the relay with a binding post of the sounder and the other binding post with the pole of a dry cell. Connect the other pole of the dry cell with the free binding post of the sounder. When the key closes the circuit through the relay, the circuit through the sounder and its dry cell is closed by the relay (Figure 165), and the sounder clicks. This is the usual arrangement in a simple telegraph office. The sounder in the first part of the above experiment can be replaced by an electric bell (Figure 166) and the key by a push button, thus showing the arrangement of the ordinary doorbell.

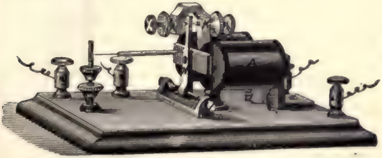


FIGURE 165

The sounder is simply an electromagnet such as was made in Experiment 159, arranged to attract a piece of soft iron held at a short distance from it by a spring. When this piece of iron is attracted toward the magnet, it strikes on another piece of iron, making a click, and so remains drawn to the magnet as long as the circuit is kept closed. Thus long and short clicks can be made.

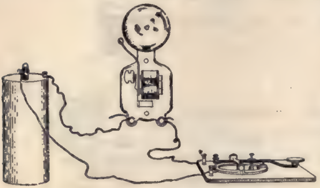
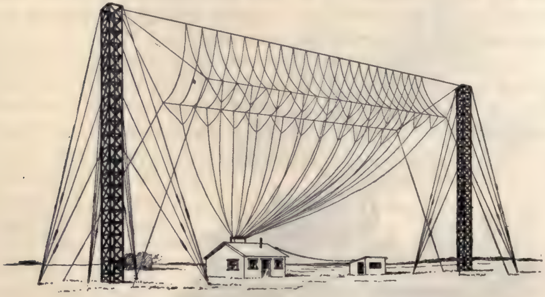


FIGURE 166

Morse arranged a combination of these long and short clicks to represent the alphabet. Thus he was able to send words from one station to another.



WIRELESS TELEGRAPH STATION, LOS ANGELES

Many improvements have been made since Morse first sent a dispatch between Washington and Baltimore, but his dot-and-dash alphabet and the electromagnet sounder and the key are still in use. Since 1832, the land has been

strung with telegraph wires and the ocean girdled with cables, and now an important event occurring in any part of the earth is known almost instantly in all other parts. The telephone, the wireless telegraph, and the wireless telephone, all electrical devices, have added to the ease of communication so that the whole earth is brought into such close relation that every part knows what all the other parts are doing.

The Greatest Electrical Discovery. — In 1831, Michael Faraday, an English physicist, made a discovery the results of which have almost revolutionized civilized man's industrial life. He found that when a magnet is quickly thrust into a coil of wire a momentary electrical current is generated in the wire, and when the magnet is *removed* a momentary current is generated in the *opposite direction*. The same effect is produced if the strength of the magnet in the coil is quickly increased or decreased, or if the coil is revolved between the poles of a magnet. This discovery makes it possible to transform mechanical energy into electrical energy and is responsible for the invention of the dynamo, the motor, and many other electrical devices.

FIGURE 167

The Telephone. — In 1875 Alexander Graham Bell first communicated by telephone from Boston to Cambridge, a distance of only a few miles. To-day man can talk across the continent. Probably no device has resulted in greater saving of time.

The simple telephone (Figure 168) consists of a hard-rubber case in which is a permanent bar magnet surrounded

at the end by a coil of fine wire. In front of the magnet, and almost touching it, is mounted a thin iron disk. Above this a concave rubber cap with a hole in the center completes the case. The ends of the coil of wire are connected with the wires from the coil of another instrument of the same kind. One of the wires from each coil may be connected with the ground.

FIGURE 168

The sound waves from the voice (or from any other source) cause the disk to vibrate back and forth in front of the magnet. These rapid vibrations of the disk result in correspondingly rapid changes in the strength of the magnet, and momentary electrical currents are induced in the coil of wire. These electrical impulses flow to the coil of wire in the other instrument, where they cause correspondingly rapid changes

U. S. Official

TELEPHONE STATION IN THE TRENCHES DURING THE WORLD WAR

in the strength of the permanent bar magnet of that instrument. The rapid variations of strength of this magnet cause the disk in front of it to vibrate in the same way that the first disk vibrated and thus to throw out sound waves similar to those of the speaker's voice. The sound is in no sense transmitted. The sound waves are transformed into electrical impulses which are transmitted to the other instrument, where they are again transformed into sound waves.

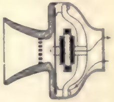


FIGURE 169

For complicated modern telephone systems, a different instrument is used for transmitting (Figure 169), but the principle involved is the same. The instrument described is still used for receiving, except that the bar magnet has been replaced by a U-shaped magnet.

DYNAMO

The Dynamo. — The dynamo is a profoundly important result of Faraday's discovery. In the dynamo, coils of wire are revolved between strong magnetic poles, and the currents of electricity which are generated are collected and delivered to the line wire to be used wherever desired. In commercial machines, there are usually several pairs of electromagnets and many

coils of wire. The coils are revolved by means of water power, steam power, or any other available power.

The electricity that is generated by the dynamo is easily transferred by wires to a long distance from the point where it is generated. Los Angeles uses electrical power which is generated in the mountains over 300 miles away. The

Courtesy of Chicago, Milwaukee and St. Paul Railway

POWER PLANT AND DAM OF THE MONTANA POWER COMPANY

This plant at Great Falls, Montana, transforms energy of running water into electrical energy by which trains are operated over 641 miles of track.

energy of the water falling at Niagara is transformed into electrical energy which is utilized for transportation and for industrial purposes at a distance of nearly 200 miles. The location of the power no longer determines the site of a factory. The factory may be located at the most convenient place possible and be run by power which is transmitted from almost inaccessible mountain retreats.

The Electric Motor. — In the dynamo the coils of wire are revolved in a magnetic field by some mechanical power, and electricity is generated in the coils. In the motor the process is reversed; electricity is passed through the coils of the motor. This causes them to revolve in a magnetic field and to produce mechanical power. In appearance and

Courtesy of Chicago, Milwaukee and St. Paul Railway

ELECTRIC LOCOMOTIVE

One of the locomotives which obtains its power from the plant pictured opposite. The most powerful electric locomotive in the world.

make-up the two machines are similar, but their work is different. The dynamo generates an electrical current; the motor uses an electrical current.

In the running of the ordinary street car, the motor and the dynamo supplement each other. At the power house are dynamos run by any convenient kind of mechanical power. The electricity that is generated is collected and

transmitted by wires and trolley through the controller to the motor under the street car. The motorman, by means of the controller, is able to turn the current into the motor or to shut it off. When the current is turned on, the motor revolves; by gearings the motion is imparted to the wheels and the car moves. Thus the electricity generated by the dynamos in power houses, wherever they may be, not only lights our homes and streets, but also enables the little motors in our homes, the powerful motors on street cars, and the giant motors of our factories to do all kinds of work for us.

Theory of Electricity. — A great deal is known about how electricity acts and what it does, but as yet little is known about what it really is. Recent experiments indicate that the atoms of matter (page 51) contain electricity, and that the negative electricity in them exists in the form of exceedingly minute particles called *electrons*. There are hundreds of these electrons in each atom, and they are held there probably by the attraction of a positive charge of electricity at the center of the atom. If the positive and negative charges in the atoms of a body are equal, the body is unelectrified.

If, however, the electrons are in any way joggled off and accumulated, a negative charge of electricity develops where this accumulation takes place. As the electrons are all negative, they repel one another and tend to move away from the point where they have accumulated to places where the accumulation is not so great. This is what happened in Experiment 156, when the electrical machine was used. An electric current is supposed to be a stream of these electrons.

SUMMARY

Certain substances may be made to take on the properties of loadstone and to become magnets. A magnet has a positive and a negative pole. The dipping needle and the mariner's compass are applications of magnetic properties.

There are two kinds of electrical charges, positive and negative. Electricity may be generated by friction, but to be of practical service it must flow continuously as a current. Lightning is an electrical discharge. Currents of electricity may be generated by means of voltaic cells, and these currents may be conducted by wires. There are many practical applications of electricity, as in electroplating, incandescent lamps, welding, flatirons, electric bells, the electric telephone, and the electric telegraph.

Michael Faraday made the greatest electrical discovery when he found that a magnet if thrust quickly into a coil of wire generates a momentary current in one direction, and if withdrawn generates a momentary current in the opposite direction. This discovery made possible the invention of the electric dynamo and the electric motor.

Recent experiments indicate that atoms of matter contain electricity, and that the negative electricity in them exists in the form of exceedingly minute particles called electrons. A current of electricity is supposed to be a stream of these electrons.

QUESTIONS

Where have you ever seen magnetism employed to man's advantage?

What is the relation between lightning and electricity?

With what simple electrical devices are you familiar?

In how many different ways do you know electricity to have been applied for your benefit?

Describe four electrical machines or appliances which you consider of particular value.

CHAPTER XVII

WITHIN THE EARTH'S CRUST

Beneath the Earth's Surface. — Many excavations and borings have been made deep into the earth's crust and it has been found that the temperature increases with the depth. The rate of increase is not the same in different places, nor is the increase always uniform in the same

San Miguel Harbor in the Azores
Notice the volcanic cone in the distance.

place. The average of a number of deep excavations in different parts of the earth gives a rise of 1° F. for each 70 or 80 feet of descent.

The greater the pressure to which rocks are subjected the more difficult it is to melt them. If it were not for this, the solid part of the earth could not be more than 40 or 50 miles

thick, as the interior heat would melt rocks under ordinary pressure. But the earth is too rigid for its interior to be otherwise than solid. So great is the pressure to which it is subjected that probably none of the material deep down in the interior of the earth is in a molten condition.

If the pressure near the surface should be decreased, or if the normal amount of heat at any place should be increased, the material might become fused, and under

AN HAWAIIAN CRATER

certain conditions might find its way to the surface. We know that heated material from below does rise toward the surface and intrude itself into the surface rocks and in some places pour forth over the surface.

What causes the uprising and outpouring of this molten material from below the surface of the earth, and how and why it reaches the surface are questions which as yet are unanswerable. But as soon as this igneous material comes within the range of observation, its properties and actions

can readily be studied. The following descriptions of some well-known typical volcanoes show some of the results of subsurface activity.

Monte Nuovo. — In 1538, on the shore of the Bay of Naples near Baiæ, that once famous resort of the Roman nobles, after a period of severe earthquake shocks there suddenly occurred a tremendous eruption. From within the earth emerged a mass of molten material blown into fragments by the explosion of the included gases. Within a few days there was formed Monte Nuovo, a hill 440 feet high and half a mile in diameter, having in the top a cup-shaped depression or crater over 400 feet deep.

So great was the explosive force of this eruption that none of the ejected material was poured out in the form of a liquid. The whole hill is made up of dust, small stones, and porous blocks of rock which resemble the slag of a blast furnace. The small fragments in such eruptions are called *ash* or *cinders*. In a week the eruption was over, and nothing of the kind has since occurred in the region.

When visited by the writer a few years ago, the bottom of the crater was a level field planted to corn. The whole process of formation of this volcanic cone was observed and recorded by residents of the region. Other similar eruptions have been observed, but perhaps this is the best known.

Vesuvius. — When the Roman nobles were building their magnificent villas and baths along the shore of the Bay of Naples, the scenic beauty of the region was greatly increased by a mountain in the shape of a truncated cone, which rose from the plain a few miles back from the shore. Its sides, nearly to the summit, were covered with beautiful fields.

In the top of the mountain was a deep depression some three miles in diameter, partly filled with water and almost entirely surrounded by precipitous rock cliffs. There were no signs of internal disturbance. Around the mountain were scattered prosperous cities, the soil was fertile, the vegetation luxuriant. To this natural fortress Spartacus, the gladiator, retreated when he first began to defy the power of Rome.

In 63 A.D. the region about the mountain was shaken by a severe earthquake which did much damage. This

VESUVIUS AND NAPLES

was followed by other earthquakes during a period of sixteen years. In August, 79 A.D., the whole region was frightfully shaken, and the previously quiet mountain began to belch forth volcanic dust, cinders, and stones, so that for miles around the sun was obscured, and a pall of utter darkness shrouded the country, lighted at intervals by terrific flashes of lightning.

A large part of the ancient crater, now known as Monte Somma, was blown away, and the villas and towns near the mountain were covered with the ash and cinders ejected. So deep were many of these buried that their sites were utterly forgotten. Pompeii and Herculaneum, after lying buried and almost forgotten for hundreds of years, have been recently partially uncovered.

These fossil cities show the people of to-day how the ancient Romans lived and built. The topography of the country and the coast line were greatly changed by this eruption. Pompeii formerly was a seacoast city at the mouth of a river. It is now a mile or more from the sea and at a considerable distance from the river.

From the date of its first historic eruption until the present time Vesuvius has had active periods and periods when quiet or dormant. Sometimes the activity is mild, and at other times tremendously violent. At times the material ejected is fragmental and at other times streams of molten lava pour down its sides. Its ever changing cone, unlike that of Monte Nuovo, is composed partly of ash and partly of consolidated lavas. Even as late as 1907 a tremendous outpouring of ash took place which devastated a considerable area.

Mount Pelee. — At the north end of the island of Martinique in the West Indies rose a conical-shaped mountain. In a hollow bowl-like depression at the top lay a beautiful little lake some 450 feet in circumference. The mountain and lake were pleasure resorts for the people of the city of St. Pierre. According to legend this mountain had been violently eruptive, but in historic time there had been no indication of this except one night in 1851 when the volcano

had grumbled and a slight fall of volcanic ash was found in the morning over some of the surrounding region.

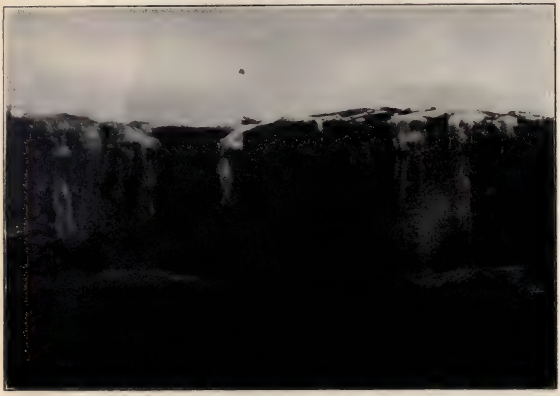
On April 25, 1902, people began to see smoke rising from the vicinity of the mountain and from this time on

Mount Pelee and the Ruins of St. Pierre

till the final catastrophe smoke and steam came out in small quantities. By May 6 the volcano was in full eruption. On the morning of May 6 the cable operator at St.

Pierre cabled, "Red-hot stones are falling here, don't know how long I can hold out." This was the last dispatch sent over the cable.

About 8 o'clock on the morning of the 8th a great cloud of incandescent ash and steam erupted, swept rapidly down the mountain toward St. Pierre, and in less than three



LAVA FLOW IN THE HAWAIIAN ISLANDS
Liquid lava flowing over a cliff.

minutes killed 30,000 people, set the city on fire, and destroyed 17 ships at anchor in the harbor. Thus within two weeks from the time of the first warning a rich and densely populated region was made a desolate, lifeless, fire-swept desert.

Distribution of Volcanoes. — The number of active volcanoes on the earth is about three hundred. Most of them are situated on the borders of the continents, on islands near

the continents, or else they form islands in the deep sea. Soundings show that there are many peaks in the sea which have not reached the surface; these are probably volcanic. Few volcanoes are far from the sea, although there is an

MOUNT LASSEN IN ERUPTION

This volcano, after being dormant for centuries, suddenly renewed its activity in 1914.

active crater in Africa several hundred miles from the Indian Ocean.

About 800 miles west of Portugal rises from the depths of the Atlantic a group of nine islands, the *Azores*. They

have an area of about 1000 square miles, and the soil is very fertile. The islands are mountainous, one of the mountains rising to between 7000 and 8000 feet above the sea. Their formation is due entirely to volcanic forces. Islands of this kind and coral islands are the only projections rising to the surface from the deep ocean floor.

In the Cordilleran region of the United States, west of the meridian of Denver, there are a score or more of lofty

THE CITY OF ST. HELENA

peaks which show conclusive evidence of volcanic origin. Until the summer of 1914 when Mt. Lassen suddenly began to erupt, none of these had been active since white men became familiar with the region. In the Aleutian Islands are numerous volcanoes which are still active, and in Hawaii are some of the greatest volcanoes on the earth.

Extinct cones are sometimes found far in the interior of continents, as the Spanish Peaks of Colorado, which are

more than 800 miles from the present coast. Many of the once active deep-sea cones have now become extinct, and their gently sloping shores have been cut back into cliffs which rise abruptly from the sea. One of these, St. Helena, rising from the depths of the Atlantic Ocean, and bounded by precipitous cliffs, is noted as being the place of exile of the Emperor Napoleon I of France.

GIANT GEYSER IN ERUPTION

Geysers. — In the north island of New Zealand, in Yellowstone National Park, and in Iceland, remarkable spouting springs called *geysers* are found. These places have had recent volcanic activity. The eruption of a large geyser is a most picturesque and startling phenomenon. Almost without warning there is thrown into the air a column of hot water from which the steam escapes in rolling clouds. It rises in some cases to a height of a hundred feet or more and is maintained at nearly this height by the ceaseless

outrushing of the water for a time varying from a few minutes to between one and two hours. Then it gradually quiets down and dies away into a bubbling spring of hot water.

The time at which most geysers will erupt is uncertain, but there is one, Old Faithful, in Yellowstone Park, which is almost as regular as a clock, the time between its eruptions being a little over an hour. This geyser plays to the height of about 150 feet and maintains the column of water for about four minutes. The Giant Geyser of the same region throws a large column of water to a height of 250 feet. It plays from one to two hours.

Experiment 161. — Fit a 250 cc. glass flask with a two-hole rubber stopper. Through one hole extend a glass tube (*a*) almost to the bottom of the flask and through the other hole a tube (*b*), 5 or 6 cm. longer than the height of the flask, to within about 1 or 2 cm. of the bottom of the flask. This last tube should be slightly drawn out at the end and bent at the top so that it slants away from the flask. Arrange the flask on a ring stand so that it can be heated by a Bunsen burner. Connect to the tube (*a*) a rubber tube long enough to reach into a water reservoir placed higher than the top of the flask and to one side. Fill the reservoir with water. (Figure 170.)

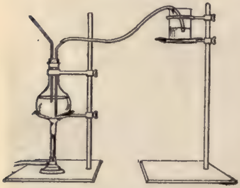


FIGURE 170

Through the tube (*b*) "suck" the air out of the flask until the water from the reservoir begins to run into the flask. A siphon will be formed which, when there is no internal pressure, will keep the water in the flask slightly above the bottom of the tube (*b*). Now heat the flask. When steam begins to form, hot water will be thrown out of the tube (*b*) until its lower end becomes uncovered and the pressure of the steam relieved. Water from the reservoir will then run in again, slightly covering the end of the tube. As soon as more steam is formed, hot water will be ejected as before.

Thus a spray of hot water is intermittently ejected from the flask as long as heating continues. We have here an action which resembles that of a geyser.

The outpouring hot water brings up with it dissolved rock and as the spray falls back and cools, this is deposited, forming craters of singular shape and grotesque beauty. On looking into these craters a smoothly lined, irregular, crooked, tubelike opening is seen to extend down into the ground. It is through this that the water finds its way to the surface. How long these tubes are nobody knows, but they must reach to a point where the heat is sufficient to raise water to its boiling point. This heat is probably due to hot sheets of lava.

FAULT LINE OF AN EARTHQUAKE

When the water in the tube is heated enough to make it boil under the pressure to which it is subjected, steam forms and some of the water is pushed out over the surface. This escape of water relieves some of the pressure, and more of the water far down in the tube expands into steam, thus throwing more water out. Huge indeed must be the reservoir to which the tube in a geyser like the Giant leads, to be able to pour out such a vast quantity of water.

Earthquakes. — In mountain regions which are young or still growing, earthquakes are not uncommon. These

are due to breaks or slips of a few inches or a few feet in the rock structure. From the place at which the break or slip takes place the motion is transmitted through the rock mass to the surface, where it causes sudden and often tremendous shocks. These slippings may occur occasionally for ages along the same fault line. Sometimes they are intense enough to cause great damage; at other times only a slight tremor is felt.

FENCE BROKEN BY THE SLIPPING OF THE EARTH ALONG A FAULT LINE

The rapidity of the transmission of the shock differs with the kind of material through which it is transmitted, varying from a few hundred feet to several thousand feet per second. The nearer a place is to the break or slip the greater is the intensity of the shock. Sometimes the crack or fault along which the movement occurs reaches to the surface and makes the displacement apparent.

If an earthquake originates under the sea, a great wave may be developed which rushes inland from the coast, causing great destruction. One of the most fearful of these waves occurred at Lisbon, Portugal, in 1755, sweeping away thousands of people who had rushed into an open part of the city to get away from the falling buildings caused by the earthquake shock.

Sometimes earthquakes are followed by terrible fires which cannot be extinguished on account of the disarrangement of the water supply. This was the case in the San Francisco earthquake. With the care taken in rebuilding

SAN FRANCISCO FIRE

The direct damage to property and loss of life by earthquake in 1906 was insignificant. The disarrangement of the water supply made possible one of the greatest conflagrations in history. Extraordinary precautions were taken in relaying the water mains of the risen city.

that city and in laying its water-mains, it is unlikely that any such disaster could ever follow another earthquake of the same sort.

Mining in Mountain Regions. — When rocks are folded and crushed, in forming mountains, heat is generated, and heated water under pressure acts upon the components of the rocks and dissolves some of their minerals, which accumulate in cracks and crevices called *veins*. When the overlying beds have been worn away, these mineral veins, formed

deep below the surface, are exposed and can be mined. Mountains are therefore the great regions for the mining of metals.

In this country mining is a most important industry in the Sierra Nevada Mountains and in the Appalachian region. In one are found great quantities of copper, silver,

PLACER MINING IN THE SIERRAS

The sand is washed from the gold by huge streams of water.

and gold, and in the other iron and coal. In the old Laurentian Mountain region, near the Great Lakes, much copper is found. The Alps and the Pyrenees are among those mountains that have few minerals.

The Story of Coal. — We have learned that warm, moist air is necessary for the activities of the bacteria of decay. Where there is too much water and not enough air the conditions are not favorable for complete decay. When plants

die and fall into water, they undergo changes but not the changes that occur in air. Most of the carbon, which in the air would be oxidized into carbon dioxide, is preserved under water.

Where vegetation grows, dies, and falls into water year after year for great lengths of time, the plant remains will

DIGGING PEAT IN IRELAND

gradually accumulate until they fill the swamps in which they have grown or the lakes which they have bordered. This explains the formation of great peatbogs in Ireland and in other parts of the world. Some of the peatbogs of Ireland are more than forty feet deep, and the spongy peat when cut and dried furnishes the most widely used

fuel of that country. That such bogs are filled lakes or swamps and that it has taken thousands of years for the peat to accumulate, is shown by the fact that hollowed

Courtesy of Taylor Coal Co.

COAL MINING IN SOUTHERN ILLINOIS

Using a pneumatic drill, preparatory to blasting. Notice the horizontal layers in which the coal lies.

logs used as canoes by prehistoric men are sometimes found buried in the peat at a depth of thirty feet or more.

If these peat accumulations should at some time be gradually submerged and covered with sand and silt, the ever-increasing pressure of the water and of the layers of sediment would gradually compress the spongy mass of vegetation

into compact layers. In the course of ages these layers would harden and change into seams of bituminous (soft) coal. The overlying layers of sand and mud would change into layers of sedimentary rock.

This process has been repeated many times in the history of the earth. In fact there are some sections where it has happened more than once over the same area, and has resulted in the formation of several seams of coal, one above the other, with layers of sedimentary rock between. If in after ages such seams of coal were heated by the folding of the earth's crust, or by some other means, the bituminous coal was changed into anthracite (hard) coal.

Sometimes miners find the roots of ancient trees, now changed into coal, projecting from the bottom of a seam of coal into the underlying rock layers that formed the soil in which this ancient vegetation grew. Sometimes the impressions of leaves and plant stems are found in the underlying or the overlying rock layers and even in the coal itself.

How dependent the greater part of the civilized world is upon nature's supply of coal, for comfort and for commerce, was shown during the coal famine of the winter of 1917–1918 in our Eastern and Middle states. Coal is a plentiful commodity in normal times, and in many sections is very cheap; but considering that nature has required ages to form and preserve it, and that what now seems an unlimited supply must some day be exhausted, the prodigal waste of coal of which recent generations have been guilty is a serious matter.

Petroleum is probably the result of the decomposition of animal and plant remains which have been subjected for ages to heat and enormous pressure. By distilling petroleum,

or crude oil as it is generally called, many different products are obtained, among which are gasoline, kerosene, benzine, paraffin, and various lubricating oils.

The crude oil itself is burned in many sections to produce heat and power. For many purposes it is better than coal,

OIL WELLS

Tapping the rock layers containing petroleum.

since the same amount of fuel can be carried in less space. The supply of oil seems to be even more limited than that of coal, but it has been wasted at times fully as recklessly. In the interest of future generations, both coal and oil should be more carefully conserved.

SUMMARY

Many excavations and borings into the earth's crust have shown that temperature increases with depth. If it were not for the tremendous pressure of outside layers of matter, the heat at the interior of the earth would probably cause the matter there to be in a molten condition. If from

solid matter heated to such a temperature, pressure should be withdrawn, or if the normal heat should be increased, the heated matter might become molten and find its way to the surface. What causes uprising and outpouring of molten material is a question that is at present unanswerable. We know only that this does occur, and has resulted in such volcanoes as Monte Nuovo, Mount Pelee, Vesuvius, and other less famous volcanoes all over the world. Geysers are spouting hot springs that are found in regions of recent volcanic activity. Earthquakes are shocks communicated to the surface of the earth from breaks or slips in rock structure of the earth's crust.

Mountains are the great regions for the mining of metals. It is supposed that the heat generated by the folding and crushing of the earth's crust in these regions has brought about the accumulation of the metal in cracks or crevices called veins. Bituminous coal is a sedimentary rock of vegetable origin, which has been deposited under such conditions that the carbon instead of being oxidized was preserved.

Questions

What is the probable condition of the earth's interior?
Describe the eruption and present condition of Monte Nouvo.
What has been the history of Vesuvius?
What is Mount Pelee's story?
Describe a geyser.
What causes earthquakes?
How has coal been formed?

CHAPTER XVIII

LIFE AS RELATED TO PHYSICAL CONDITIONS

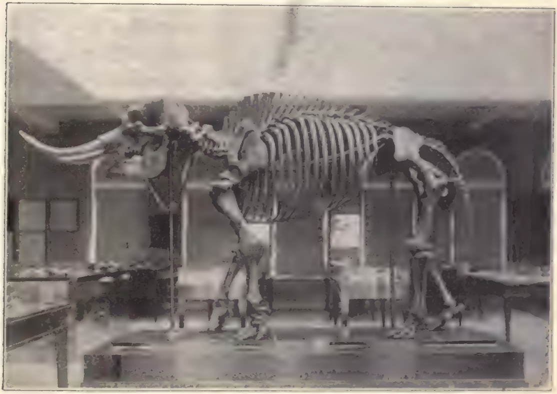
Ancient Life History. — As the rock layers of the earth are explored, *fossils* of different kinds of plants and animals are discovered. The fossils of the more recent rock layers

PETRIFIED TREES
Found near Holbrook, Arizona.

correspond very closely to the plants and animals that are found upon the earth to-day, but the older the layers, the less they correspond. There seems to have been a gradual development in life forms through the past ages, a frag-

mentary record of which is engraved upon certain of the sedimentary rocks. Rocks which were formed under different conditions contain different species of life-forms, showing that throughout all time the geographic condition has had a marked influence upon plants and animals.

The rocks and fossils also show that the geographical conditions of certain areas have varied greatly. Some



Skeleton of an Ancient American Elephant
Found near Los Angeles, California.

regions have been below and above the sea several times. Regions now cold have been warm, and those now dry have been wet, and *vice versa*. Thus the life in certain areas has suffered great changes by the geographical accidents to which the region has been subjected. The petrified forests near Holbrook, Arizona, show some of the most remarkable tree fossils ever found and indicate that the region has been subjected to remarkable geographical changes.

Distribution of Life. — Plants and animals are found wherever the conditions are suitable for their existence. The surface of the earth is a universal battlefield of plants and animals struggling to exist and to increase. They extend themselves wherever attainable space is opened. But barriers may oppose their spread and geographical accidents may drive them from areas which they had heretofore held. The retreat of the sea may cause a change in the position of shore life. In the water a land barrier or an expanse of deep water may prevent the spread of shore forms. On the land a mountain uplift, a desert area, or a water barrier may limit the space occupied by animal and vegetable species.

GILA MONSTERS

These are very poisonous reptiles of the southwestern American desert.

Certain plants and animals are much more widely distributed than others. Plants like the dandelion and thistle, whose seeds are easily blown about by the wind, spread rapidly, while trees like the oak and chestnut spread slowly. As plants have not the power to move about, they cannot

distribute themselves as easily as animals. Certain birds which are strong of flight are found widely distributed over regions separated by barriers impassable to other animals.

Some of the present barriers to life distribution have come into existence in comparatively recent geological time. There is good reason to believe that the British Isles and Europe were formerly connected, and that in very ancient times Australia was joined to Asia. It is also believed that for long ages North and South America were separated by a water barrier and that even after they were once connected, the Isthmus of Panama was again submerged.

Canada Thistle

One of the most widely distributed of plants.

These are but a few illustrations of the changes in the earth's surface which have affected the distribution of animals and plants. Climatic changes like that which brought about the great ice advance of the Glacial Period have affected in a marked degree the distribution of life. It is thus found that when a study is made of the present distribution of life, careful attention must be given to the present and past geographical conditions of the region.

Effect of the Glacial Period upon Plants and Animals. — All plants and animals were forced either to migrate before the slowly advancing ice or to suffer extermination. Individual plants, of course, could not move, but as the ice

spread toward the south with extreme slowness and with many halts, the plants of colder latitudes found conditions suitable for their growth ever opening toward the south. They were thus induced to spread in that direction, so that at the time of the greatest extension of the ice the plants suitable to a cold climate had penetrated far to the south of their former habitat.

As the ice receded, these cold-loving plants were forced to follow its retreat or to climb the mountains in order to obtain the climate they needed. They did both, so that in areas once covered by the ice, plants similar to those of far northern regions are found on the tops of the mountains in middle latitudes. What was true of the plants was true also of the animals.

Waterfalls Due to Glaciation. — As the ice spread over the country it filled the river valleys in many places with débris. When the ice melted away, some rivers could no longer find their old courses and were forced to seek new ones. In its new course a stream might fall over a cliff.

The Merrimac furnishes a fine example of water power due to glaciation. The great manufacturing cities of Lowell, Lawrence, and Haverhill would not exist had not the river been displaced from its previous channel by the glacial ice, and in developing its new valley come upon ledges. The Niagara is another notable example of vast water power due to the displacement of drainage by the ice. It is probable that in pre-glacial time there was a river which carried off the drainage of the area now drained by the Niagara, but it did not flow where the Niagara now flows.

Thus we see that the hum of the spindle and the lathe are often but the modulated whispers of those ancient forces

Yosemite Falls

A wonderfully beautiful waterfall due to glacial action.

which thousands of years ago sorted the rock materials and built the vast continental ice palaces of the Glacial Period.

Adaptability of Life. — There is hardly a place on the earth's surface not adapted to some form of life. Even upon the ice-bound interior of Greenland a microscopical plant and a tiny worm have found a home. The dry desert regions have a few plants with small leaves or, like the cactus, with no true leaves. Lack of leaves prevents the evaporation of the water from plants and so protects them from drought.

CACTI

These are adapted to desert life because they have no leaves from which water can evaporate.

Another example of adaptability is the fact that the small animals of the desert are generally of a sandy color, which makes them hardly distinguishable from their desert surroundings. The large ones are swift, strong runners, like the antelope and ostrich,

or, like the camel, are able to travel for long distances without water.

RATTLESNAKE COILED READY TO SPRING

The color of these reptiles makes them hardly distinguishable from the surrounding desert.

In the colder regions the plants have the power of rapid growth and germination during the short season when the snow has melted away. Then, during the long winter, they lie dormant but unharmed under the snow and ice. The animals are either able, like the reindeer, to live upon the dry mosses, lichen, and stunted bushes, or else upon other animals. Their color, like that of the polar bear, often blends with their surroundings.

A HERD OF REINDEER

This animal is of invaluable service to man in polar regions.

Some animals have a wide range of adaptability, like the tiger, which is found from the equator to Siberia. But usually the range of an animal species is much more restricted, since it is seldom able to adapt itself to widely differing conditions. The surrounding region, the elevation, the temperature, the amount of moisture, the soil, the kinds of winds and their force, all have a marked

effect upon the *fauna* (animals) and *flora* (plants) of a country.

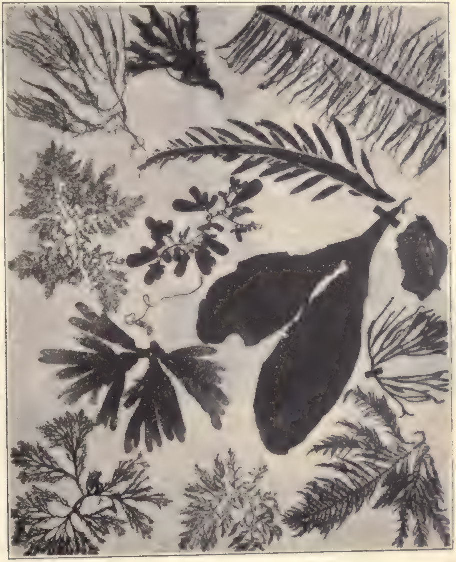
The species that thrive in a region must have adapted themselves to the existing conditions, yet other animals and plants may be as well adapted for certain regions as those now inhabiting them. Striking examples of this

CALIFORNIA RABBIT DRIVE

In some localities rabbits become such a pest that the inhabitants turn out in a body, drive them into inclosures, and kill them.

are the English sparrow and the gypsy moth, which have spread with such tremendous rapidity since their introduction into this country. The rabbit in Australia and southern California is another striking example. The adaptability of plants to a new region is also illustrated by the Russian thistle which was introduced into this country in 1873 and which has now become a national pest.

Life of the Sea. — The plants living in the sea are nearly all of a low order. The mangrove trees which border some tropical shores represent their highest type. The most abundant of sea plants, the seaweeds, have no flower or



Different Kinds of Seaweed

seed or true root, although most of them have an anchoring device by which they are attached to the bottom. Their food is absorbed from the surrounding water. They have developed little supporting tissue, but instead have bladder-like air cavities or floats, which enable them to maintain

an upright position or to float freely in the water. Usually they abound near the shore where the water is shallow.

The vast surface of the open sea supports few plants except the minute one-celled plants, the *diatoms,* of which there are many species and an almost infinite number of individuals. These furnish about the only food for the animals of the open sea except that obtained by preying upon one another.

A great quantity of detached seaweed (*Sargassum*), filled with multitudes of small marine animals and the fishes which prey upon them, covers the surface of the middle Atlantic, the center of the oceanic eddy. Through this Columbus sailed from the 16th of September to the 8th of October, 1492, greatly to his own astonishment and to the terror of his crew, who had never before heard of these "oceanic meadows."

A SMALL SHARK
Photographed under water.

The animals of the sea vary in size from the microscopic *globigerina* (page 400), whose tiny shells blanket the beds of the deeper seas, to the whale, that huge giant of the deep, in comparison with which the largest land animals are but pygmies. Although monarch of all the finny tribe, it is not a fish at all, but a mammal which became infatuated with a salt-water life and so through countless ages has more and more assumed the finny aspect. It is obliged to rise

to the surface to breathe. It cares for its young like other mammals.

Here, too, are found the jellyfish, the Portuguese man-of-war (Figure 171), some fishes, many crustaceans, a few insects, turtles, snakes, and mammals. Most of these animals are lightly built and are well equipped for floating and swimming. Some sea animals, like the oyster, barnacle, and coral polyp, are fixed, and rely upon the currents of the water to bring them their food, while others, like the crab, the lobster, and the fish, move from place to place in search of prey.

FIGURE 171

In the warmer seas the surface water is often filled with minute microscopical animals which have the power, when disturbed, of emitting light, so that when a boat glides through these waters at night, a trail of sparkling silver, called *phosphorescence*, seems to follow in the wake.

Between the surface and the bottom of the deep ocean there seems to be a vast depth of water almost devoid of life. This region, like the bottom of the ocean, has been little explored and there may be life here which has not been discovered. From the bottom of the sea the dredge has brought up some very curious forms of life. Here under tremendous pressure and in profound darkness have been developed species of carnivorous fishes.

Some of these have large, peculiarly well-developed eyes and others have not even the rudiments of eyes. As the light of the sun never penetrates to these depths, it would seem at first that eyes could be of no use, but it has been found that some of the animals of the ocean bottom have the power of emitting light in some such way as the glow-worm and firefly do, and it is probable that it is to see

this phosphorescent light that the eyes of the animals are used. There are no plants here and the life is much less abundant and less varied than near the surface.

Flying Fish
Notice how the front fins have become wing-like

There is but little variation in the conditions surrounding the animals of the sea, and so the organs corresponding to these conditions are not diverse. Living in a buoyant medium dense enough to support their bodies, and of almost unvarying temperature, the sea animals have never required or developed varied organs for locomotion, like the wing, the hoof and the paw, or for protection from cold, like the feather, the hair, or wool. It is true that certain sea dwellers, like the seal, are covered with hair, but these air breathers were probably originally a land type and have acquired the habit of living in the water.

Seals
Originally land animals.

The highest traits of animal life, such as are found in land animals, have not been required or acquired by the sea animals, and although the number of species and kinds is very great, there is not found among them the same grade of intelligence or power of adaptability, as among the land animals.

Life of the Land. — The highest development of both plant and animal life is found upon the land. Here at the meeting place of the solid earth and its gaseous envelope, subjected to great variations in amount of sunlight, moisture, temperature, and soil, the plants and animals have acquired a marvelous variety of forms and structures to adapt them to their varied surroundings, and to enable them to secure a living.

PRICKLY PHLOX
Notice the thorns by which it protects itself.

Some plants lift their strong arms high into the air to intercept the sunbeams before they strike the earth, while others clothe the surface with a dress of varied green. In some plants, odor, nectar, or juicy berries attract the animals whose aid is needed for fertilizing and scattering their seeds, while in others, noxious odors, prickles, thorns, and acrid secretions ward away animals destructive to their welfare.

The highest perfection of beauty, utility, and productiveness among plants has been reached by those of the land.

The animals of the land, surrounded by the air, which bears no food solutions to inert mouths, must be well endowed with the power of motion in order to procure their food. They must either crawl over the surface or be provided with appendages to support their weight against gravity. There is no floating indolently in the air as in the water. Movement, exertion, search, are the requisites of life on land. The eggs and young, as a rule, cannot be abandoned to hatch and to care for themselves; the nest, the burrow, the den must be provided. This is the realm of homes.

BIRD'S NEST
A simple home.

The land animals are also the most intelligent. Birds long ago solved the problem of flight for a body heavier than air, which is now being successfully solved by man after years of effort. Certain animals, like the bee, the ant, and the squirrel, have the provident habit of storing up food in the summer against a day of need. Other animals, like the birds, have learned to migrate to a warmer clime when winter comes. The beaver is probably the pioneer in hydraulic engineering. When he feels the need of a water reservoir, he builds a dam and makes it. To-day many a swamp in the northern states owes its origin

to him. Wonderful indeed is the intelligence of many of the land animals, due in large part to their development amid varied geographical conditions.

Double Beaver Dam and Beaver House

In the foreground, one of the dams is plainly visible. In the background is a second dam running almost parallel to the first. To the right in the quiet water is the beaver house. To the left are stumps of trees that were felled by the beavers. Picture taken in Estes Park, Colorado, by Frank M. Hallenbeck of Chicago.

Distribution of Animals. — An examination of a globe shows (1) that the land is massed around the north pole, (2) that the three continental masses to the south are separated from one another by wide seas, and (3) that while two of these are connected by narrow strips of land to northern continents, the third is entirely separated from all other land.

But slight changes in elevation would connect the northern continents with one another. As they are so closely related

to one another, it might be expected that the animals of these continents would resemble one another, particularly in the more northern parts. This is true. Bears, wolves, foxes, elk, deer, and sheep of nearly related species are found distributed over the northern continents.

OSTRICHES
The largest of all birds.

The animals of the southern continents are much less nearly related. The ostrich, giraffe, zebra, and hippopotamus are among the characteristic animals of Africa which are not found elsewhere. In South America the tapir, great anteater, armadillo, and llama are among the animals not represented elsewhere. Both of these continents, however, have animals closely related to those of other great divisions, showing that their present isolation has not continued far back in geological time.

OPOSSUM
Many opossums have no pouch but carry their young on their backs.

The animals of Australia differ greatly from those

of the other continents. The quadrupeds here are *marsupials*, animals which usually carry their young in a pouch. The only members of the family existing at present elsewhere are the American *opossums*. The largest of the marsupials is the great kangaroo, which measures between seven and eight feet from its nose to the tip of its tail. Although it has four feet, yet it runs by making extraordinary

KANGAROO FEEDING

leaps with its strong hind feet. Here is also found one of the most singular of all living animals, the duckbill, the lowest of all quadrupeds, which in its characteristics resembles both quadrupeds and birds.

All this seems to show that the distribution and development of the animals of the different continents have been largely dependent upon the former geographical relations of the land masses. The native animals of a region are

not necessarily the only ones suited to it; animals from other places may be even better adapted, but they have been kept out by some natural barrier. This is particularly evident in the case of Australia, where the weak native animals would have been readily displaced by the stronger animals of Asia could these have reached that isolated continent.

Life on Islands. — Islands which rise from the continental shelves were probably at one time connected with the continents, but have since been separated by the submergence of the intervening lowland. The animals and plants of such islands are similar to those of the adjacent large land masses. But *oceanic islands* possess only those types of plants and animals which originally were able to float or fly to them over the surrounding water expanse. Indigenous mammals, except certain species of bat, are wanting. Birds are abundant.

THE DODO

Although the dodo is extinct, sufficient remains have been found to enable scientists to tell how it looked.

On the tropical islands the cocoanut palm furnishes the main supply of vegetable food, clothing, and building material. Many of the species of both plants and animals are different from those of the nearest continent and even of the adjacent islands. So complete has been the isolation of the life on these islands for so long a time that it has been possible for great differences in species to develop. Large unwieldy birds unable to fly or run rapidly have been found on some oceanic islands, the

dodo of Mauritius, now extinct, being one of the most notable.

The absence of predatory animals has probably made the development of such forms possible. The great species of tortoise from the Galapagos Islands perhaps owes its development to the same cause. Nowhere else have such huge tortoises been found. The remarkable fauna and flora found on oceanic islands may be regarded as due to their geographical isolation.

Life of Man as Affected by Physical Features. — Mountains offer a retreat to persecuted people as well as to animals. Here are often found the races which once inhabited

A Cottage in the Scotch Highlands

the surrounding plains, but which have been driven from them by conquerors. The people of Wales and the Scotch Highlanders are probably descendants from more ancient inhabitants of the island than those in control to-day. The

Pyrenees, the Caucasus, and the Himalaya Mountains each contain tribes which were driven from the lower plains, but have been able in these retreats to withstand invaders who were too powerful for them in their former homes.

Old-fashioned customs still maintain their hold in remote mountain regions long after they have been discarded in the surrounding country where intercommunication is easier. In some of the Scotch Highlands the natives still

CRIPPLE CREEK

One of the largest mining camps in the world.

cling to their ancient dress, and in sections of the southern Appalachian Mountains many of the customs of the early pioneers are still common.

In mountain regions rich in ores, mining naturally becomes the chief industry, and here, if there were any secluded native inhabitants, these have been replaced by the energetic miners from distant places. The deep and remote valleys and mountain sides have become the homes of mining camps and cities. Railroads have been built to these, overcoming almost impassable obstructions, and ore crush-

ing and smelting works supply the places of the mills and factories of the manufacturing cities. When the ore fails, the army of workers moves on, and the city, once thriving and booming, becomes suddenly simply an aggregation of empty dwellings.

Modern irrigation has developed many barren uplands into wonderfully successful agricultural districts.

Effect of Mountains on History. — Not only have mountains been retreats for the vanquished, but they have been barriers against further conquest by the conquerors. It is very difficult for an army to traverse a mountain range. For a long time the Alps hemmed in the power of Rome. One of the greatest exploits of Hannibal and later of Napoleon was the passage of these same mountains.

In our own country the Appalachian Mountains acted for a long time as an impassable barrier to the expansion of the Thirteen Colonies. The trails across them were so long and difficult that it was many years before the fertile plains on their western side became populated. The Mohawk valley opened a comparatively easy route at the north, but the Cumberland trail at the south was long, circuitous, and full of places suitable for Indian ambuscade.

The little mountain country of Switzerland is a buffer state for the rest of Europe. Afghanistan, rough, mountainous, and desert, is a buffer state for Asia. It may happen that mountain boundaries are so broad and complicated that a little country inserts itself along the boundary of two powerful nations and is able to protect itself from being absorbed by either. The little country of Andorra, containing only 150 square miles, situated in a lofty valley on the southern slope of the Pyrenees, with a population

not exceeding 10,000, has remained independent for nearly a thousand years in spite of its powerful neighbors.

Life on Plains. — The life conditions on plains are very different from those in places where the irregularities of the surface are great. Movement is as easy in one direction as in another, and the lines of travel tend to be straight.

A HERD OF CATTLE ON THE GREAT PLAINS

There is usually no reason for an accumulation of population in any one place, so the population tends to be uniformly distributed.

As movement from place to place is easy, it is not difficult for the inhabitants of a plain to mass themselves together at one point. In case of invasion by a superior enemy there is no place for hiding or safe retreat, and subjection or extermination are the alternatives, unless the plain is so large that the enemy is unable to spread over it. In the case of animals this has been shown in the practical extermination of the American bison and antelope.

In the case of men it was shown on the plains of Russia in the thirteenth century when the Tartars conquered the region and threatened to overrun Europe.

Another instance was that of the fatal invasion of Russia by Napoleon. The Russians, unable to find a strategic place to make a stand, retreated farther and farther into the plain. The depletion of Napoleon's army, due to the

A Herd of Bison

extent of territory which must be held in his rear, the distance from his base of supplies, and the rigor of the Russian winter, forced him to begin that disastrous retreat, the fatal results of which probably led to his final overthrow.

Plains have always played an important part in history. Here armies can march and countermarch with comparative ease. Large bodies of men can easily be assembled. Military stores can be readily collected and all the operations of war carried on without natural obstructions. Thus

it happens that certain plains have been the seats of almost innumerable wars. The great plain of the Tigris and Euphrates was the gathering ground and battlefield of vast ancient monarchies. The plains of the Po have been the arena in which embattled Europe has settled some of its deadliest strifes, while the level lands of Belgium have been dyed again and again with the blood of thousands and

A PART OF THE PLAIN OF WATERLOO, BELGIUM

thousands of Europe's bravest sons. The brutal invaders of 1914 cynically admitted that they overran Belgium because it was the shortest and easiest military route to Paris.

Life on Coastal Plains. — The valuable minerals of the earth are usually found in the older rocks, so there is no mining on a coastal plain, and because the rivers are shallow and fall over no ledges as they flow across these plains, no great water power for manufacturing can be developed. The sluggish streams are often dammed and small water

powers developed, but there is not the fall necessary for large factories, except sometimes in the hilly region back near the old land where the rivers have developed rather deep and narrow valleys, and mill ponds of considerable size may be made.

As the different kinds of soil lie in belts, agriculture will vary with the belts. In warm climates rice can be raised along the shore where the land is marshy. On the sandy land most profitable truck farming is possible if the transportation facilities are good. In many places in the southern states these sandy areas support fine forests of pine (page 344), which are most valuable for the production of turpentine, tar, and lumber. Where the soil is not too sandy and the climate is warm, cotton is raised in abundance. The materials for making glass, pottery, and brick are widespread over coastal plains.

CRUDE TURPENTINE STILL

Turpentine is distilled from the pitch of the pine.

The cities on coastal plains are usually found either (1) near the coast, where the rivers have formed harbors and so have made ocean commerce possible, or (2) at the head of navigation in the rivers where water transportation begins, or (3) still farther up the river at the fall line, where manufacturing on a large scale is possible.

The *fall line* is the point on a river where its bed passes

from the harder rock of the old land to the softer material of the coastal plain. The softer material is worn away more easily than the hard material, and falls or rapids are produced suitable for water power. A glance at a map of the southeastern United States will show that the principal cities lie in line nearly parallel to the coast. Of those

PINEAPPLES

near the coast are Norfolk, Wilmington, Charleston, Savannah, Jacksonville; at the fall line, Trenton, Philadelphia, Richmond, Columbia, and Augusta.

Advantages of Harbors. — The importance to mankind of good harbors cannot be overestimated. The latest and greatest of all wars has especially emphasized this. Thousands and thousands of men have been sacrificed in efforts to obtain or to defend harbors.

No civilized country by its own products can supply all the wants of its inhabitants. Since earliest times man has been

a barterer of goods. The sea offers him an unrestricted highway for his traffic. Harbors he must have to load and unload his wares safely.

Although many of the best harbors of the world are found along depressed coasts, such as the harbors of New York, San Francisco, London, Liverpool, and Bergen, yet there are several other sorts of harbors. The delta of a great river may afford a good harbor, as those of New Orleans and Calcutta. Harbors may be formed by sand reefs and spits, like those of Galveston, Provincetown, and San Diego. The atolls of the mid-Pacific and even the submerged craters of volcanic islands afford safe resting places where ships may ride out the storms.

MINOT'S LEDGE LIGHTHOUSE

Situated on a reef about 15 miles southeast of Boston.

All natural features have a greater or less influence upon the inhabitants of

the earth, but perhaps none has so directly and obviously influenced man's activities as has the kind of coast on which he lives. Europe, with its harborful, and Africa with its almost harborless coasts are in striking contrast to each other. This difference between the inducements

San Francisco Harbor,
A harbor due to a depression of the coast.

to travel and commerce which the two continents afford is one of the factors in producing the marked difference in progress attained by the native peoples of the two continents. They stand to-day as types on the one hand of economic progress and on the other of stagnation.

The Phœnicians, the Carthaginians, the Greeks, the English, and the other great nations of the world have

felt the enticing allurement of a captive sea waiting in their harbors like a steed for them to mount and ride away in quest of the world's best. Thus they have extended their conquest and influence far beyond the homeland. All nations regard adequate outlet to the sea as essential

CALIFORNIA, U. S. A.
One of the finest harbors in the world.

to progress. The struggle of all the great world powers to strengthen their navies, no matter what the cost, shows with what jealousy the products of their ports are guarded.

Coasts with harbors give their people the facilities and inducements for seeking the unknown, while the harborless coasts confine the aspirations of their inhabitants to the products immediately around them. A glance at the

coast line and harbors of Greece shows one cause of its ancient civilization and a reason why the Greeks were "always seeking some new thing."

SUMMARY

Physical conditions have a great effect on the distribution of life upon the earth. It is hard for living things to cross high mountains, broad oceans, or vast deserts. When confined to certain climates and areas, plants and animals naturally adjust themselves to these.

Life in the sea is so simple that plants and animals there are not forced to become as highly developed as are those of the land. On land there are greater ranges of climate and other physical conditions, so that plants and animals have been forced to a high development in order to survive. Man is one of the greatest forces at present affecting land life. He transplants and transports animals and plants according to his desires. The physical conditions decide whether or not they shall live.

The elevation of mountain regions, difficulty of travel, and lack of agricultural lands cause these sections to be sparsely settled by backward peoples unless mining has attracted progressive settlers. Mountains have always furnished safe retreats for persecuted peoples and have been barriers to further conquest.

Life on the plains is usually most varied. But since the plains offer no safe retreat, the inhabitants of level lands have always been subject to invasion and conquest, and the native animals to extermination. Coastal plains offer no opportunities for mining, but certain kinds of manufacturing and agricultural pursuits are peculiar to such regions. Access to

the sea, which is the oldest and easiest highway, is essential to the progress of a nation.

Questions

What do the rock layers show in regard to the history of life?

Give several reasons why the same kinds of plants and animals are not found all over the earth.

How has the glacial period affected plants and animals and man's activities?

What plants and animals do you know that are particularly adapted to the conditions in which they live?

How does the life of the sea differ from that of the land?

How has the distribution of animals been affected by geographical conditions?

How have different physical features of the earth affected man's life and history?

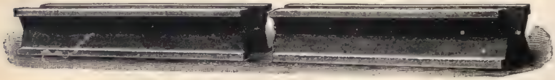
APPENDIX

Units. — To measure any physical quantity a certain definite amount of the same kind of quantity is used as the *unit.* For example, to measure the length of a body, some arbitrary length, as a foot, is chosen as the unit of length; *the length of a body is the number of times this unit is contained in the longest dimension of the body.* The unit is always expressed in giving the magnitude of any physical quantity; the other part of the expression is the numerical value. For example, 60 *feet*, 500 *pounds*, 45 *seconds.*

In like manner, to measure a surface, the unit, or standard surface, must be given, such as a square foot; and to measure a volume, the unit must be a given volume, such, for example, as a cubic inch, a quart, or a gallon.

Systems of Measurement. — Commercial transactions in most civilized countries are carried on by a decimal system of money, in which all the multiples are ten. It has the advantage of great convenience, for all numerical operations in it are the same as those for abstract numbers in the decimal system. The system of weights and measures in use in the British Isles and in the United States is not a decimal system, and is neither rational nor convenient. On the other hand most of the other civilized nations of the world within the last fifty years have adopted the *metric system,* in which the relations are all expressed by some power of *ten.* The metric system is in well-nigh universal use for scientific purposes. It furnishes a common numerical language and greatly reduces the labor of computation.

Measure of Length. — In the metric system the unit of length is the *meter*. In the United States it is the distance between two transverse lines on each of two bars of platinum-iridium at the temperature of melting ice. These bars, which are called "national prototypes," were made by an international commission and were selected by lot after two others had been chosen as the "international prototypes" for preservation in the international laboratory on neutral ground at Sevres near Paris. Our national prototypes are preserved at the Bureau of Standards in Washington. The two ends of one of them are shown below. The only multiple of the meter in general use is the *kilometer*, equal to 1000 meters. It is used to measure such distances as are expressed in miles in the English system.



ENDS OF METER BAR

The Common Units in the Metric System are

1 kilometer (km.)	=	1000 meters (m.)
1 meter	=	100 centimeters (cm.)
1 centimeter	=	10 millimeters (mm.)

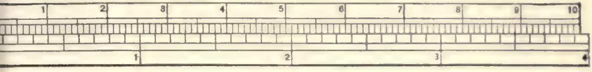
The Common Units in the English System are:

1 mile (mi.)	=	5280 feet (ft.)
1 yard (yd.)	=	3 feet
1 foot	=	12 inches (in.)

By Act of Congress in 1866 the legal value of the yard is $\frac{3600}{3937}$ meter; conversely the meter is equal to 39.37 inches. The inch is, therefore, equal to 2.540 centimeters.

The unit of length in the English system for the United States is the *yard*, defined as above. The relation between the centimeter scale and the inch is shown below.

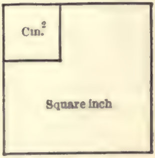
100 MILLIMETERS = 10 CENTIMETERS = 1 DECIMETER = 3.937 INCHES.



INCHES AND TENTHS

CENTIMETER AND INCH SCALES

Measures of Surface. — In the metric system the unit of area used in the laboratory is the square centimeter (cm.^{2}). It is the area of a square the edge of which is one centimeter. The square meter (m.^{2}) is often employed as a larger unit of area. In the English system both the square inch and the square foot are in common use. Small areas are measured in square inches, while the area of a floor and that of a house lot are given in square feet; larger land areas are in acres, 640 of which are contained in a square mile.

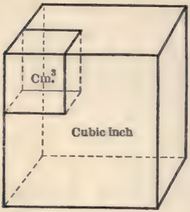


SQUARE CENTIMETER AND SQUARE INCH

The square inch contains $2.54 \times 2.54 = 6.4516$ square centimeters. The relative sizes of the two are shown in the accompanying figure.

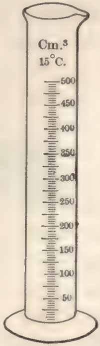
The area of regular geometric figures is obtained by computation from their linear dimensions. Thus the area of a rectangle or of a parallelogram is equal to the product of its base and its altitude ($A = b \times h$); the area of a triangle is half the product of its base and its altitude ($A = \frac{1}{2}b \times h$); the area of a circle is the product of 3.1416 (very nearly $\frac{22}{7}$) and the square of the radius ($A = \pi r^2$); the surface of a sphere is four times the area of a circle through its center ($A = 4\,\pi r^2$).

Cubic Measure. — The smaller unit of volume in the metric system is the *cubic centimeter.* It is the volume of a cube the edges of which are one centimeter long. The cubic inch equals $(2.54)^3$ or 16.387 cubic centimeters. The relative sizes of the two units are shown here. In the English system the cubic foot and cubic yard are employed for larger volumes. The cubical capacity of a room or of a freight car would be expressed in cubic feet; the volume of building sand and gravel or of earth embankments, cuts, or fills would be in cubic yards.



CUBIC CENTIMETER AND CUBIC INCH

The unit of capacity for liquids in the metric system is the *liter.* It is a decimeter cube, that is, 1000 cubic centimeters. The imperial gallon of Great Britain contains about 277.3 cubic inches, and holds 10 pounds of water at a temperature of 62° Fahrenheit. The United States gallon has the capacity of 231 cubic inches.



CYLINDRICAL GLASS GRADUATE

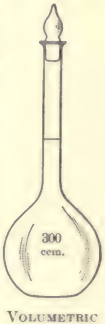
Common Units in the Metric System:

1 cubic meter ($m.^3$)	= 1000 liters (l.)
1 liter	= 1000 cubic centimeters ($cm.^3$)

Common Units in the English System:

1 cubic yard (cu. yd.)	= 27 cubic feet (cu. ft.)
1 cubic foot	= 1728 cubic inches (cu. in.)
1 U. S. gallon (gal.)	= 4 quarts (qt.) = 231 cubic inches
1 quart	= 2 pints (pt.)

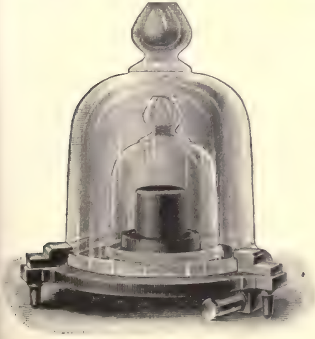
The volume of a regular solid, or of a solid geometrical figure, may be calculated from its linear dimensions. Thus, the number of cubic feet in a room or in a rectangular block of marble is found by getting the continued product of its length, its breadth, and its height, all measured in feet. The volume of a cylinder is equal to the product of the area of its base (πr^2) and its height, both measured in the same system of units.



Volumetric Mask

Liquids are measured by means of graduated vessels of metal or of glass. Thus, tin vessels holding a gallon, a quart, or a pint are used for measuring gasoline, sirup, etc. Bottles for acids usually hold either a gallon or a half gallon, and milk bottles contain a quart, a pint, or a half pint. Glass cylindrical graduates and volumetric flasks are used by pharmacists, chemists, and physicists to measure liquids. In the metric system these are graduated in cubic centimeters.

Units of Mass. — The unit of mass in the metric system is the *kilogram*. The United States has two prototype kilograms made of platinum-iridium and preserved at the Bureau of Standards in Washington. The *gram* is one thousandth of the kilogram. The latter was originally designed to represent the mass of a liter of pure water at 4° C. (centigrade scale). For practical purposes this is the kilogram. The gram is


Standard Kilogram

therefore equal to the mass of a cubic centimeter of water at the same temperature. The mass of a given body of water can thus be immediately inferred from its volume.

The unit of mass in the English system is the *avoirdupois pound*. The *ton* of 2000 pounds is its chief multiple; its submultiples are the *ounce* and the *grain*. The avoirdupois pound is equal to 16 ounces and to 7000 grains. The "troy pound of the mint" contains 5760 grains. In 1866 the mass of the 5-cent nickel piece was legally fixed at 5 grams; and in 1873 that of the silver half dollar at 12.5 grams. One gram is equal approximately to 15.432 grains. A kilogram is very nearly 2.2 pounds. More exactly, one kilogram equals 2.20462 pounds.

All mail matter transported between the United States and the fifty or more nations signing the International Postal Convention, including Great Britain, is weighed and paid for entirely by metric weight. The single rate upon international letters is applied to the standard weight of 15 grams or fractional part of it. The International Parcels Post limits packages to 5 kilograms; hence the equivalent limit of 11 pounds.

Common Units in the English System:

1 ton (T.)	=	2000 pounds (lb.)
1 pound	=	16 ounces (oz.)
1 ounce	=	437.5 grains (gr.)

Common Units in the Metric System:

1 kilogram (kg.)	=	1000 grams (g.)
1 gram	=	1000 milligrams (mg.)

The Unit of Time. — The unit of time in universal use in physics and by the people is the *second*. It is $\frac{1}{86400}$ of a mean solar day. The number of seconds between

the instant when the sun's center crosses the meridian of any place and the instant of its next passage over the same meridian is not uniform, chiefly because the motion of the earth in its orbit about the sun varies from day to day. The *mean solar day* is the average length of all the variable solar days throughout the year. It is divided into $24 \times 60 \times 60 = 86{,}400$ seconds of mean solar time, the time recorded by clocks and watches. The sidereal day used in astronomy is nearly four minutes shorter than the mean solar day.

The Three Fundamental Units. — Just as the measurement of areas and of volumes reduces simply to the measurement of length, so it has been found that the measurement of most other physical quantities, such as the speed of a ship, the pressure of water in the mains, the energy consumed by an electric lamp, and the horse power of an engine, may be made in terms of the units of *length*, *mass*, and *time*. For this reason these three are considered *fundamental units* to distinguish them from all others, which are called *derived units*.

The system now in general use in the physical sciences employs the *centimeter* as the unit of length, the *gram* as the unit of mass, and the *second* as the unit of time. It is accordingly known as the *c. g. s.* (centimeter-gram-second) system.

PROJECTS

Project I. — *How a Boy Scout Determines Directions by the Stars,* pages 9 and 10

Determining directions by the stars requires a little practice. The necessary information may be found on pages 9 and 10 of the body of the book. When you are in some locality where you know the points of the compass, turn to the northern sky on a clear night and see if you can locate the Big Dipper (Diagram, p. 10).

Remember that the stars in the north appear to go around in a circle once every twenty-four hours (p. 8), and so you may find the Big Dipper near the zenith (the point of the sky directly overhead), down near the horizon, or somewhere on its circuit between these two points. Rotate the diagram on page 10 about Polaris as a center, and you will observe all the relative positions to the North Star which the Big Dipper may occupy.

If you live in the southern portion of the United States, part of the Big Dipper may disappear below the horizon when the constellation swings below the North Star; but the "pointers" are generally in sight. If you will follow the direction indicated by these "pointers," as shown in the diagram on page 10, you will find Polaris very easily. It is a lonesome-looking star, because it is fairly bright and is surrounded by stars of lesser brilliance. To identify it further, see if you can trace the Little Dipper. The North Star forms the tip end of the handle (Diagram, p. 10).

Now see if you can locate the constellation of Cassiopeia's Chair. It is about as far from the North Star as the Big Dipper and always on the opposite side of Polaris from that constellation (Diagram, p. 10). Above the North Star, it is M-shaped; below Polaris, it is inverted into a W-shaped cluster.

Learn to recognize these three northern constellations so that you can trace them readily, and you will be able to locate the North Star without difficulty. Then when you are in a strange locality, the northern sky will seem familiar to you and will guide you unerringly.

When you have located the North Star, face it with arms outstretched to right and left. The right arm points to the east; the left arm to the west.

Project II. — *How a Boy Scout Determines Directions by Day,* pages 23, 24, 37, 38

(*a*) To determine directions with the aid of a watch, point the hour-hand toward the sun. To do this accurately, hold the watch, face upward, in the palm of your hand. Hold a match or a straight twig upright at the edge of the dial and turn the watch until the hour-hand points toward the match and the shadow of the match lies directly along the line of the hour-hand.

The point on the dial halfway between the hour-hand and the figure XII will then indicate south with a fair degree of accuracy. Thus, if the hour-hand is at X, the figure XI on the dial will point toward the south; if the hour-hand is at III, the mark on the dial that indicates 1 : 30 will point toward the south.

Explanation. — The reason for this is that on a day of average length (twelve hours) the sun appears to describe a half-circle in the sky while the hour-hand of your watch is describing a complete circle. If the watch and the sun both described a semicircle in the same length of time, the figure XII would always point toward the south if the hour-hand were aimed at the sun. But since the hour-hand travels its circuit twice as fast as the sun, it is necessary to halve the distance between the hour-hand and the figure XII in order to find the point on the dial that indicates the south.

(*b*) A reliable pocket compass may be had for a reasonable sum. Learn from some surveyor the declination (p. 38) for your immediate section so that you may determine the true north accurately. You may purchase magnetic charts from the United States Geolog-

ical Survey which will show the variation for any section accurately. Only be sure that you have the latest issue of the chart, because the declination of the needle slowly changes from time to time (pp. 38, 39).

Set your compass in a place, as nearly level as possible, away from the vicinity of steel and iron. Then allow for the declination and you will have the true north.

If you cannot afford a compass, make one as suggested in Experiment 8, pages 37 and 38. To use this satisfactorily, you will have to train your eye to gauge the declination. This you can do by floating the cork compass at the side of a manufactured compass as often as you have opportunity. Train the eye to recognize the declination of the floating compass by comparing it with the measured declination on the manufactured compass.

Put the cork in your pocket and carry the magnetized needle in a small glass phial. You can set this compass wherever there is water.

(*c*) Hard and fast rules for telling direction by the growth of mosses and lichens and other vegetation in forests are responsible for a good deal of current misinformation. Writers sometimes give specific information for certain regions, and amateur woodsmen get the impression that the instructions are true for all times and places.

Practiced guides, like the Indians of old, can tell direction within a very few degrees of perfect accuracy by observing forest vegetation. This ability comes of long and acute observation and cannot be cultivated by rule. A few basic facts may be given, along with advice that accurate information for any section can come only of close observation and reasoning.

As a rule, mosses and lichens grow on the cool or shady side of a tree. In the North Temperate zone, this is *generally* the northern side, but it may vary with the immediate surroundings and with the direction of the prevailing winds and rains. For instance, trees growing on a north slope, where the sun has no access to them, are coolest and dampest on the side toward the ground, and may therefore have moss on the south side.

To offset this cause of confusion, it is well to remember that in such sections underbrush and small plants grow more densely on a northern exposure than on a southern exposure, because the sun does not get a chance to dry out the north slope so thoroughly. The practiced guide knows too that mosses grow where they can have not only shade but an abundance of moisture. The prevailing winds, therefore, may have something to do with local variation of moss growths.

If you are near a forest, make a study of conditions that prevail there and report on them to the class. Take your compass with you. Find out on which side of trees the moss growths usually occur. If not on the north side at all times, see if you can offer a reason for the variation. Study the vegetation and soil on all slopes, if you are in a hilly or mountainous region, and report the results of your observations.

If you will be constantly on the alert, in whatever sections you traverse, you will eventually accumulate much valuable forest lore.

PROJECT III. — *How a Boy Scout Determines Latitude by the North Star*, page 32

Choose a straight post or tree from which the North Star may be sighted. Nail a smooth piece of board, about a foot square, to the east or west side of the post or tree so that you can sight the North Star along the face of the board.

Drive a six-penny or eight-penny wire nail straight and securely into the upper north corner of the face of the board (K), and suspend a plumb line from the nail (KL). Now from the south edge of the board, sight along the face of it until you can see the North Star immediately under the wire nail. Then move the point of a knife, or scratch-awl, along the face of the board near your eye until you can just sight the North Star over the edge of the blade. When the knife reaches this spot, stick the point of the knife-blade carefully into the board. If you have sighted accurately, the star can be seen just under the nail and over the knife blade. If the eye

be moved ever so little up or down, either the nail or the knife-blade will cut off the light of the star.

Now you are ready to draw three lines on the face of the board, and you probably will need an artificial light. With a ruler, draw a line exactly corresponding to the plumb line (*KL*). Then draw

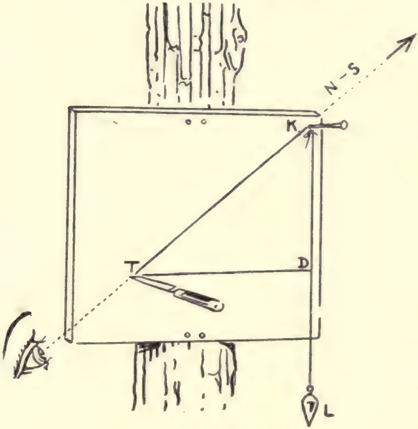


FIGURE 1

a straight line from the point of the nail to the edge of the knife blade (*KT*). With a carpenter's square, draw a line (*TD*) at right angles to the plumb line. The number of degrees in the angle at *T* will be approximately equal to your latitude. If you haven't a protractor to measure this angle, take the board to the laboratory and measure the angle.

EXPLANATION. — If we could draw a line from the center of the earth to the point where we stand (*KL*, Figure 2), we should have a line running "straight down" (p. 24). Since the weight of a plumb line points to the center of the earth, the direction of the plumb line

(KL, Figure 1) is "straight down." Now if a line should be drawn at the earth's surface (TD, Figure 2) at right angles to the first line, it would indicate our horizon, or line of vision along the earth's surface. The line TD on the board (Figure 1) is drawn at right angles to the plumb line and may, therefore, be regarded as our horizon line.

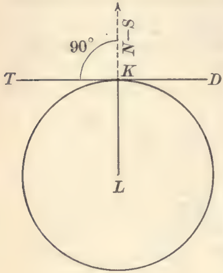


FIGURE 2

Now suppose we were standing at the north pole (K, Figure 2). The North Star would be directly overhead, and the line of light from the star to the eye (K—N–S, Figure 2) would be at right angles, 90°, to our horizon line (TD, Figure 2). Thus the angle of the North Star above the horizon line at the north pole, 90°, equals the latitude of the north pole, 90°.

Suppose we should travel along a meridian line to a point midway between the north pole and the equator, 45° latitude (K, Figure 3). The North Star would no longer be overhead, but would be about half-

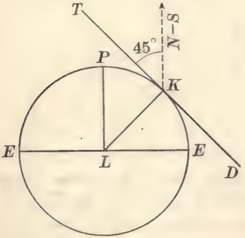


FIGURE 3

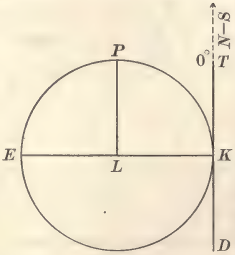


FIGURE 4

way between the zenith and the horizon. The line of light from Polaris to the eye (K—N–S, Figure 3) would, therefore, form about half a right angle, 45°, with our horizon line (TD).

Suppose we should travel on to the equator, 0° latitude (K, Figure 4). The North Star would then be on the horizon. The line of light

from it ($K—N–S$, Figure 4) would be identical with the horizon line (TD), and there would be no angle, 0°. From this it can be seen that, in order to measure our latitude, we need only measure the angle of the North Star above the horizon.

Your calculations may be as much as one degree off, one way or the other. But if you will make your observations on a night when the constellation of Cassiopeia is just as high above the horizon as the North Star, you will get accurate results. See the "Boy Scouts' Handbook," p. 96, and Figure I, on page 10 of this book, and report on this to the class.

PROJECT IV. — *Star Projects Varying with the Seasons*, pages 1–18

The two other constellations in the northern heavens that are shown in the diagram on page 10 are Cepheus and the Dragon (Draco). After you are able to locate with certainty the other three constellations we have talked about, you will probably be able to trace these two constellations.

Two of the best known stars in the northern heavens are Vega and Arcturus. The two stars forming the inside edge of the Big Dipper next to the handle form a line which points past the head of the Dragon toward a large, brilliantly white star. This is Vega. The two stars that form the bottom of the Little Dipper form a line pointing away from the Pole toward a very bright reddish star of the first magnitude. This is Arcturus, mentioned on page 7 of this book.

Since the earth, by reason of its revolution around the sun as well as its rotation, gradually changes its position in relation to the stars, there is a noticeable change of the evening sky map from month to month. The best way to make a study of the evening sky for any particular month is to obtain a copy of the "Monthly Evening Sky Map,"[1] a little journal for amateur astronomers. By means of this, from month to month, you may identify the planets, important constellations (such as Scorpio, in midsummer; and Orion, in midwinter) and important stars, including Sirius, the Dog-Star,

[1] "The Monthly Evening Sky Map," Leon Barritt, Publisher, 367 Fulton Street, Brooklyn, New York.

the brightest star in the heavens, which appears low on the southern horizon in midwinter.

Among the many interesting books on the study of the stars are the following:

"Earth and Sky Every Child Should Know," Rogers. Doubleday, Page & Co.

"Easy Star Lessons," Proctor. G. P. Putnam's Sons, New York.

"The Book of Stars," Collins. D. Appleton & Co., New York.

For those whose interest in the study of the heavens does not wane, a most useful and interesting device is "The Barritt-Serviss Star and Planet Finder." This is a cleverly constructed, revolving chart which furnishes in a moment's time a map of the heavens for any hour of any night of the year. Address Leon Barritt, Publisher. (See footnote, p. 569.)

PROJECT V. — *How to Clean Drain Pipes*, pages 56 and 57

Nothing has a more important bearing on the health of a household than the condition of drain pipes leading from sinks, washbowl, and bathtubs. Typhoid, diphtheria, and other deadly germs find ideal breeding places in the grease and filth of these drains. Housekeepers who keep their homes otherwise immaculate sometimes forget the cleansing of drains because the unsanitary accumulations are out of sight. No sink drain ought ever to go without attention until the waste water runs slowly or the pipes are clogged.

If a sink becomes clogged, a cupful of lye in a wash-boilerful of boiling water will generally cut the grease that has gathered and holds other waste accumulations. Chloride of lime used in the same proportions will accomplish the same purpose. The solution should be poured in fast enough so that it will run through with considerable force. If this fails, cover the opening to the drain and fill the sink with a second boilerful of the solution. Then with a force-cup (familiarly known as a "plumber's friend") force the mixture down the drain pipe. This seldom fails to produce the desired result.

To keep a sink drain in sanitary condition, flush it daily, preferably in the evening, with a dishpanful of clear boiling water in which a tablespoonful of washing soda has been dissolved. Once a week, flush with a wash-boilerful of boiling water in which a teacupful of chloride of lime has been dissolved. Lye must be handled with such great care that it is best not to use it unless its use is made necessary by clogged pipes. At any rate, chloride of lime is fully as effective for disinfecting and almost as effective for cleansing.

Project VI. — *How to Prepare Certain Acids and Bases for Removing Stains*, page 57

The most common acids for removing stains are lemon juice, lactic acid (the acid found in sour milk and buttermilk), tartaric acid, oxalic acid, and salts of lemon in solution. If spots can be removed without the use of oxalic acid or salts of lemon, so much the better. They are more apt to cause injury to fabrics than milder acids, and besides they are rank poisons.

The most common bases for taking out stains are ammonia, baking soda, washing soda, borax, and Javelle water.

The least familiar of these acids and bases are probably tartaric acid, oxalic acid, salts of lemon, and Javelle water.

Tartaric Acid. — This may be prepared by dissolving any given quantity of cream of tartar in an equal or even smaller bulk of water. The same effect may be had by wetting the stain thoroughly with water and applying the dry cream of tartar. This is the more common way of using it, because tartaric acid prepared as above indicated will not "keep."

Oxalic Acid. — Dissolve commercial oxalic acid crystals in ten times their bulk of water. If this solution proves too weak, add crystals until desired strength is obtained. Painters use a very strong solution of this (about one part of oxalic acid crystals to two parts of water) for bleaching stains out of wood. The crystals dissolve much more quickly in boiling water, and the solution should be used hot for bleaching wood.

Salts of Lemon. — This is the common name for oxalate of potash. It may be purchased at a drug store under either name. It may be used in solution, but is generally applied to a stain after the fabric has been soaked in water — as in the case of cream of tartar.

Javelle Water. — Dissolve one fourth of a pound of chloride of lime in a quart of boiling water, and a pound of washing soda in a second quart of boiling water. Pour the two solutions together and set the mixture aside to settle. Pour off the clear liquid and store it in bottles or a stone jug. This is Javelle water, a very effective bleaching solution for white cotton or linen.

Helpful Hints on the Treatment of Stains

Direction for removing stains must always depend both on the nature of the fabric and on the kind of stain. Vegetable fibers, such as linen and cotton, will stand more vigorous treatment than wool, silk, or other animal fibers. The most common stains are those of acids, alkalies, ink, grass, iron rust, fruit, mildew, tar, paint, grease, and oil. The last four enumerated are more easily removed by substances that will dissolve them or absorb them. They will be discussed later. Here we are interested chiefly in stains that may have to be removed by undergoing chemical changes.

Many stains may be removed by solution (Project XXVIII) or absorption (Project XXXIV) before long exposure to the air brings about certain chemical changes that set the stain. Since strong acids and bases must be employed to remove such stains after they are set, it is especially desirable that stains on delicate or colored fabrics be treated while fresh. Thus the use of strong chemicals, with consequent risk of injury to the cloth, may be avoided.

Where chemicals must be used, the milder agents should be tried first, and the stronger acids or bases used only as a final resort. When the stronger acids are used, they should be followed by ammonia in order to neutralize the acid. It is often wise, especially in the case of a valuable fabric, to make tests with a scrap of the same or a similar piece of goods before running any risk with the treasured article.

Oxalic acid and salts of lemon may be used with care on any kind of vegetable or animal fabric that is *white.* They will bleach colored fabrics, but the color may often be restored by the use of ammonia followed by chloroform. The most useful acid for removing stains is probably tartaric acid. It cannot be made strong enough to injure fabrics, and if the cream of tartar is mixed with an equal bulk of salt, it is not likely to cause colors to run. It is only slightly poisonous.

Project VII. — *How to Remove Acid Stains*

Many acids will stain fabrics of any sort. Some acids which will not affect white goods will stain colored goods, especially blues and blacks.

To Bleach Acid Stains from White Cotton or Linen. — (*a*) Wash the article, dip the stain in Javelle water, and rinse in clear cold water. Or, (*b*) dampen the stain and expose it to the fumes of burning sulphur.

To Neutralize Acid Stains in Goods of Any Fabric or Color. — Apply ammonia to the stain. In the case of colored silk or other delicate colored fabrics, apply the ammonia very gently. A camel's hair brush or a medicine dropper is recommended for the purpose. Take care not to rub the ammonia into the stain or it may cause the color to run. If the color is affected, apply chloroform to restore it.

Project VIII. — *How to Remove Alkali Stains*

White or Colored Goods. — If fabrics of any sort are stained by washing soda, lime, or other strong alkalies, moisten the stain with lemon juice, vinegar, or tartaric acid. Afterwards apply chloroform, if necessary to restore the color.

Project IX. — *How to Remove Ink Stains*

Fresh Ink Stains. — (*a*) If possible, ink stains should be treated immediately, before they have a chance to be set. Wet the fresh

ink spot immediately with water, or preferably with warm milk, and cover it with dry starch, French chalk, or salt, or weight a clean blotter on the stain. Remove the absorbent or change the blotters as the ink is absorbed. Keep the spot wet and repeat the operation until the ink is removed. This treatment is safe for any fabric. If the milk leaves a greasy stain, remove it with benzine or carbona.

(*b*) For any fabric that will stand soap and water, melt pure tallow and pour it over the fresh ink stain. If the article is small, dip it in the tallow. Remove the tallow after an hour or so with hot water and soap. Many dyers and cleaners do this first, because it cannot hurt the fabric and it may obviate the risk of using chemicals.

Old Ink Stains. — Test. — Before using any chemical on an ink stain that has set, make the following test, if possible, of the ink that caused the stain: Write a few lines on a piece of paper and allow the ink to dry. Better than this, take a specimen of writing with the ink that is several days or weeks old. If when the paper is dipped in water the ink blurs or smirches badly, it probably contains a coal-tar product known as nigrosine. The effect of certain acids on this coloring matter is to make it almost indelible. In such a case use a strong solution of washing soda or apply Javelle water to the stain with a brush or sponge and rinse in clear cold water from time to time. Do not use an acid.

To Remove Ink That Does Not Contain Nigrosine. — Old-fashioned inks depended on a compound of iron for the black coloring. *Most* modern blue-black inks have, in addition to an iron compound in their make-up, certain aniline dyes. Acids mentioned below change the iron compound so that it will dissolve in water, but the acid must be followed by a bleaching compound to remove the color of the aniline dyes. Following are the treatments suggested. The first two are very mild treatments; the third mild, but much more effective; while the fourth is to be reserved for very stubborn stains.

(*a*) Wet the stain with lemon juice and cover with salt. To hasten the action of the acid and salt, expose to the sun, hold in the steam of a tea-kettle, or lay the cloth over a plate that is used as a cover for a sauce pan containing boiling water. Afterward expose the spot to the fumes of sulphur (sulphur dioxide) or apply Javelle

water with a brush or sponge. Rinse thoroughly in clear cold water. Repeat if necessary.

(*b*) Soak in sour milk and salt or in buttermilk and salt. Cover the stain with salt and expose to the sun.

(*c*) Wet the stain thoroughly and cover with cream of tartar. Proceed then as in (*a*). Most ink stains will yield to this treatment.

For Delicate or Colored Fabrics. — Wet the stain thoroughly and cover with cream of tartar mixed with an equal bulk of salt. Sponge very lightly with clear water and expose to sulphur fumes. If the color is affected, apply ammonia with a camel's-hair brush or a medicine dropper and follow with an application of chloroform. Repeat if necessary.

(*d*) *For Stubborn Spots on Heavy White Goods.* — Wet the stain thoroughly and rub in salts of lemon or oxalic acid with a small stiff brush, keeping the stain over a hot plate as in (*a*). Sponge with ammonia and bleach with sulphur fumes or Javelle water as in (*a*). Rinse in clear water. Salts of lemon and oxalic acid are very poisonous if taken internally.

PROJECT X. — *How to Remove Grass Stains*

(*a*) Sponge out the stain while it is *fresh* with clear water. If this is not sufficient, sponge the stain with alcohol before it is set. Do not use alcohol if the stain is several hours old.

(*b*) Another effective method for fresh stains is to cover the stain with lard, allow it to stand thus for 24 hours, and then wash with hot water and soap.

(*c*) If the stain is old, the green coloring matter of the grass has undergone chemical changes by being exposed to air. Alcohol will then change the green spot to a dark brown spot that will not wash out. Wet an old stain and apply cream of tartar and salt in equal bulk. If this leaves a light brown stain, sponge it with water. If colored fabric is affected by this treatment, sponge with ammonia and follow with an application of chloroform.

(*d*) An old grass stain on white goods may be removed by bleaching with a mixture of equal parts of clear water and Javelle water.

Project XI. — *How to Remove Rust Stains*

The simplest method is to wet the stain with lemon juice, cover with salt, and expose to the sun.

If this fails, wet the stain and cover it with a mixture of equal parts of cream of tartar and salt. Expose the spot to the sun, hold it in the steam of a tea-kettle, or over a hot plate as suggested in Project IX. This may be used on any kind of fabric and is not likely to injure even colored fabrics. If it does affect colors, sponge lightly with ammonia and follow with an application of chloroform.

On any white fabric, dilute oxalic acid, salts of lemon, or Javelle water may be used. Follow either of the first two with ammonia and rinse in clear water.

Project XII. — *How to Remove Fruit Stains*

Fresh Fruit Stains. — All fruit, tea, and coffee stains should be treated while they are fresh. Plum, peach, and blackberry stains are especially stubborn if they become set. While the stain is fresh, stretch the cloth over a bowl, cover the stain with baking soda or washing soda, and pour boiling water through the cloth until the soda is dissolved. If necessary, let the cloth sag into the water in the bowl for a while.

Another method is to soak the fresh stain in warm milk and salt, cover with salt, and expose to the sun.

Old Fruit Stains. — To a fruit stain on any white fabric, apply Javelle water, salts of lemon in solution or dilute oxalic acid and follow with ammonia.

For wool, silk, delicate and colored fabrics, wet the stain with a mixture of equal parts of alcohol and ammonia. Sponge gently with alcohol until stain is removed. Sponge gently with chloroform to restore color if necessary.

Project XIII. — *How to Remove Mildew*

(*a*) If the fabric will stand it, boil in strong borax water.

(*b*) Soak the stain in buttermilk or sour milk and salt, cover with salt, and expose to the sun.

(c) Soak the stain in lemon juice. Apply common salt and powdered starch or salt and expose to the sun.

(d) Keep the stain wet with Javelle water and expose to the sun.

(e) Wash the stain with Ivory soap or any pure white soap. Rub in powdered chalk with a flannel cloth. Cover with more chalk and lay in the sun.

(f) Dissolve two teaspoonfuls of shavings of any hard white soap in four teaspoonfuls of water, add a teaspoonful of starch, one half teaspoonful of salt, and the juice of half a lemon. Mix thoroughly and apply to the mildewed stain with a brush. Keep the spot wet with this mixture until the stain disappears.

Of these six methods, *b*, *c*, and *f* are probably the most commonly used.

PROJECT XIV. — *How to Test Fabrics with Acids and Bases*, pages 55–57

There are numerous ways of testing fabrics to determine what they are made of. Experts can easily distinguish the fibers of silk, wool, cotton, linen, and other fabrics under the microscope. The various fibers have their characteristic appearances and odors while burning that may be observed and distinguished by experimentation. Very reliable tests may also be made with the aid of certain acids and bases.

To Distinguish between Wool and Cotton. — If you are in doubt as to whether a piece of goods is wool or cotton, boil a sample of it for five minutes in a strong solution of caustic soda (sodium hydroxide). If it is all wool, it will dissolve completely. If it is all cotton, it will not be visibly affected, except possibly to appear somewhat shrunken and a bit more silky. If the fabric is mixed wool and cotton, the wool will be dissolved, leaving the cotton that was woven with it. If it is mixed wool and silk, the wool will dissolve first, leaving the silk. About 15 or 20 minutes more of boiling will dissolve the silk.

Caustic soda and other strong alkalies dissolve wool very readily, but do not so affect cotton. In fact, cotton is treated with caustic

soda as the first step in mercerizing it. Silk also dissolves in caustic soda, but not so readily as wool.

To Distinguish between Silk and Mercerized Cotton. — Put a little concentrated hydrochloric acid in a test tube and heat it gently, stirring it with a chemical thermometer until the thermometer registers 50° C. or a little less. Immerse a sample of the fabric in the acid and keep it there for three or four minutes, being careful to keep the acid at a fairly even temperature. If the fabric is silk, the sample will be dissolved. If it is mercerized cotton, it will remain intact. Concentrated hydrochloric acid will not dissolve either wool or cotton.

To Distinguish between Cotton and Linen. — The simplest test to determine whether a fabric is linen or cotton is made, not with an acid or an alkali, but with olive oil. Thoroughly soak the fabric, or a sample of it, in olive oil for about five minutes. Remove the excess of oil by pressing the cloth between blotters. If the fabric is linen, it will now be translucent. If it is cotton, it will be as opaque as it was before soaking in the oil.

A most interesting book for anyone who is interested in chemistry in everyday life is "The Amateur Chemist," A. F. Collins. D. Appleton & Co.

PROJECT XV. — *How to Make Soap from Waste Fats at Home,* page 57

Collecting enough waste fats for a batch of soap is likely to prove a tedious performance. If through carelessness or impatience a pupil then fails to produce soap, there is a discouraging loss of time, effort, and money. It is recommended, therefore, that the first batch of soap be made a community affair for the entire class; or that the class be divided into groups, each group undertaking the project.

If there is a school lunch-room or cafeteria, pupils may be able to enlist the aid of the school kitchen in collecting waste fats for the experiment. If not, pupils may each contribute a few ounces of fat from their home kitchens and may divide the expense of

borax and potash. Experiments in soap-making on a very small scale are somewhat difficult to perform. It will be found easier to produce soap from five pounds of fat than from five ounces.[1] Follow the directions carefully and patiently:

Into a six-quart iron or heavily enameled vessel put 2 quarts of water and heat it to boiling. Remove from the stove and dissolve 1 can of Babbitt's potash in the hot water.

In a third quart of hot water, dissolve one half pound of borax.

Pour the borax solution into the potash solution and set the mixture aside to cool.

Melt 5 pounds of fat and strain it through three layers of cheesecloth. Allow this fat to cool to a soft paste-like consistency.

The next step requires patience. Add the fat, a spoonful at a time, to the potash-borax solution, and stir each spoonful into the solution slowly and carefully. After the fat is all in, stir the mixture slowly for fifteen minutes.

If at the end of this time the soap is not of a paste-like consistency, let it stand, giving it an occasional slow stirring. Your success may be immediate, or your patience may be taxed for a day or more. Do not give up.

When the mixture has become pasty, pour it into a rectangular pan lined with oil paper. As soon as it hardens, it may be cut into bars. It should be allowed to dry out for several weeks before it is used. This soap is of very good quality and may be used for toilet purposes.

Coloring, Perfuming, and Molding. — It is recommended that the pupil confine his first efforts to producing soap. After he has made a batch or two, he may wish to try experiments with coloring and perfuming. Coloring matter, such as eosin (a very small amount), should be added after about ten minutes of stirring and before the mixture begins to become jelly-like. A few drops of oil of lemon or some other perfume may also be added at the same time.

After the soap has hardened, it may be remelted with a gentle heat and poured into molds lined with oiled paper.

[1] Collecting waste fats at home though tedious work is to be encouraged, as the soap made therefrom will repay the effort.

Project XVI. — *How to Remove Dents in Wood*, pages 64–67

A heavy blow of a hammer will leave a dent in wood. What happens is that the molecules of the wood at this particular place have been forced into smaller space; that is, the spaces between them have been lessened (see p. 67 of this book). If the wood had been as elastic as rubber, the molecules would have regained their original positions immediately; but wood has not great elasticity.

If now we can cause the wood to absorb enough heat and moisture, the molecules will be driven back to their original relative positions. Heat an iron very hot. Soak several thicknesses of soft brown paper in hot water. Lay this pad of wet paper over the dent and cover it with a double thickness of cloth soaked in hot water. Apply the hot iron to the cloth just above the dent, and let it stand until the cloth and paper are nearly dry. If the dent is deep, this process may have to be repeated several times.

Project XVII. — *How a Boy Scout Makes Fire without Matches*, page 72

Five things are necessary to produce a rubbing-stick fire: a drill or spindle, a fire-block or hearth, a hand-socket, a bow, and tinder.

Figure 5

In choosing wood for making the drill and fire-block, great care must be exercised. The wood should be dry and long-seasoned, but sound. Gummy and resinous woods should be avoided. A test for good wood for this purpose is that the wood-dust ground off shall be smooth to the touch, not gritty or sticky. Two of the best and most widely distributed woods are cottonwood and willow. Better even than these are the cedar, the cypress, or the tamarack, if they can be had. If none of these is at hand, try soft maple, elm, poplar, sycamore, or buckeye.

Drill. — Out of a straight dry branch or piece of seasoned wood, whittle a roughly rounded spindle, about 12 inches long, and not more than $\frac{3}{4}$ inch in diameter. Sharpen the two ends of the stick, as shown in Figure 5.

Fire-block. — Take a piece of wood not more than 12 inches long, 2 or 3 inches wide, and not more than $\frac{3}{4}$ inch thick. On one

FIGURE 6

side of this board, well toward one end, cut a notch $\frac{1}{2}$ inch deep, and bevel it slightly toward the under side of the board. About $\frac{1}{8}$ inch, or less, from the tip of the notch make a little hollow or pit in the board, as shown in Figure 6, A.

Hand-socket. — If nothing better is at hand, take a pine or hemlock knot that will just fit comfortably into the palm of the hand. Make a pit in the center of one of the flat surfaces of the knot, about $\frac{1}{4}$ inch in diameter and $\frac{1}{4}$ inch deep.

FIGURE 7

If you are going to practice fire-making on camping trips, you will find it a great saving of time to have a socket made for your permanent use. Take a solid block of wood 5 or 6 inches long, $1\frac{3}{4}$ inches wide, and $1\frac{1}{2}$ inches thick. Set in the middle of one face of this block a piece of soapstone or marble 1 inch square and about $\frac{3}{4}$ inch deep. In the center of this piece of stone make a small smooth pit, $\frac{3}{8}$ inch wide and $\frac{3}{8}$ inch deep. Smooth and round the opposite face of the block so that it will fit your palm comfortably and can be grasped firmly. The socket is now ready for use (Figure 7).

Bow. — (*a*) For this, any slightly curved *rigid* branch or stick, 18 tc 24 inches long, may be used. Fasten a thong of buckskin,

belt-lacing, or of any pliable leather, about $\frac{3}{8}$ inch wide, to the bow, as shown in Figure 8. The thong should be just long enough so

FIGURE 8

that when it is given one turn around the drill it will be stretched taut (Figure 9).

Tinder. — Any dry, finely divided material that readily bursts into flame from a spark is called tinder. Shredded cedar bark, a wad of dry grass, crumpled dry leaves, willow catkins, scraped cedar or spruce wood will serve admirably. Any observing person will be able to find plenty of good tinder in a forest.

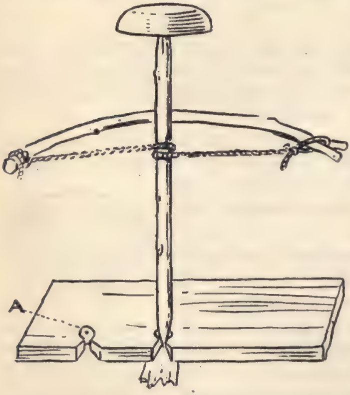


FIGURE 9. — TOOLS IN POSITION TO MAKE FIRE. At *A* is shown a hole that has been bored in producing fire.

In addition to this tinder, which is used to nurse the glowing spark into flame, the fire-maker should have at hand a collection of twigs, long-stemmed dry grass, splinters, slivers of dry bark, etc., to be used as kindling for the larger fuel that is to follow.

To Make Fire. — Set the fire-block on firm ground or on flat rocks or on any foundation where the block can be kept from slipping or joggling. Slip a thin chip under the notch of the hearth.

Turn the thong of the bow once around the drill. If the thong is of the right length, it will now be taut.

Set one point of the drill into the pit near the point of the notch of the fire-block, fit the upper end into the hand-socket, and with your left hand hold the drill perpendicular to the block. Anchor the fire-block with your left foot, and steady your left hand by resting your left wrist against your left shin. This is to enable you to *keep the drill steadily in an upright position* (Figure 9).

Now with the right hand draw the bow slowly and steadily back and forth the full length of the thong, pressing lightly on the hand-socket. Keep the bow horizontal, and do not touch the drill with it as you saw back and forth. The twirling motion of the drill soon makes it bite into the block, boring out powdered wood. When it begins to smoke, put a little more pressure on the socket and drill faster. When the dust comes out in a compact mass and the smoke increases to a considerable volume, you probably have the spark.

Carefully lift the fire-block so as to leave the smoking powder undisturbed on the chip. Gently fan this with your hand into a bright glow. Then put a wad of tinder gently over the glowing powder and blow until the tinder bursts into flame. Follow this with the kindling and your fire is started.

N. B. If you are left-handed, you will probably reverse the directions for employing the right and left hands.

PROJECT XVIII. — *How to Make Fire with Flint and Steel*, page 73

It is much easier to make fire with flint and steel than to produce a rubbing-stick fire. Flint and steel and even tinder fuse may be bought of dealers in camping outfits. Many lighting devices for pocket use are based on the principle of striking fire from flint with steel.

But neither the flint and steel nor the tinder have to be purchased. Any piece of steel and any piece of quartz or hornstone or flint may be made to serve your purpose. If you want to be sure of having "punk" that will be sure to catch the spark, soak pieces

of cotton wicking in a solution of saltpeter and dry them thoroughly. Of the materials to be found in a forest nothing is better than dried fungus growths of various sorts. Thoroughly dried puff-balls, or the flat white fungus growths found on decaying tree-trunks, or dried lichens or moss are among the best materials. Dust or very fine shavings scraped from dry cedar bark, spruce, or pine will catch the spark readily.

To obtain the spark, rest the flint on the "punk" and strike downward with the steel along the edge of the flint so as to throw the shower of sparks into the "punk."

When you have the spark in the "punk," nurse it into a glow exactly as in the case of the rubbing-stick fire, transform the glowing spark into flame with the aid of tinder, and add the kindling and larger fuel gradually until your fire is established.

Project XIX. — *How to Operate a Fire-extinguisher*, pages 79 and 80

The principle of the fire-extinguisher which produces carbon dioxide is carefully explained on pages 79 and 80 of the body of the book. Every pupil of junior high school age ought to know how to operate one of the extinguishers without a moment's hesitation.

Every modern fire-extinguisher has explicit directions for operating it printed on the metal container. These directions should be followed to the letter. It is especially important that the extinguisher should be discharged occasionally so as to have the machine always charged with fresh chemicals.

Build a small fire in the open, away from all buildings, and use a fire-extinguisher to smother the fire. Remember that the purpose of these machines is to cover the fire with a blanket of carbon dioxide gas. Play the spray from the machine over the whole fire so as to cut off the oxygen from all burning material.

When you have extinguished the fire, refill the cylinder according to directions, not neglecting to wash it out thoroughly before refilling. If you are at all in doubt as to whether you have refilled

correctly, discharge the extinguisher again in a second experiment with a small bonfire.

One of the machines that generates carbonic acid gas also produces a foam, the bubbles of which imprison the carbonic acid gas and form a sort of foamy blanket that is especially effective in extinguishing burning oils.

Another very commonly used extinguisher, which is compact enough to be convenient for automobile use, is filled with a liquid that contains carbon tetrachloride. When this liquid comes in contact with heat, it is readily converted into a heavy gas which smothers the fire just as carbon dioxide does. This machine is operated like a simple hand-pump.

Project XX. — *How to Make a Fireless Cooker at Home,* page 91

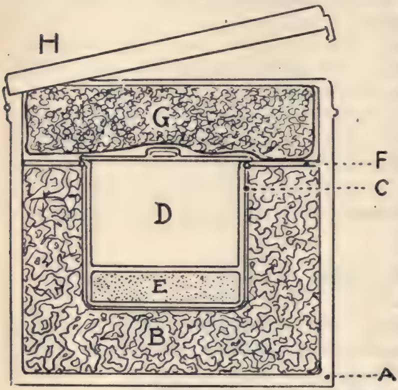
A very satisfactory fireless cooker may be made at home at relatively slight expense.

The Box or Container. — The outside of the box may be a tightly built wooden box, an old trunk, a galvanized iron ash can, a large lard tin or butter firkin.

A well-built conveniently sized box (Figure 10, *A*), with a hinged cover (Figure 10, *H*), fitted with a hasp lock is perhaps the most satisfactory container, although the cooker incased in metal has the advantage of being fireproof. If a box is to be used, its size will depend on the size of the metal nest which holds the cooking vessel (Figure 10, *C*). If possible, the box and the nest should be large enough to accommodate a six-quart cooking vessel (Figure 10, *D*). There must be enough space in the container to allow for *at least* four inches of packing material above, below, and all around the metal nest.

Packing or Insulating Material. — For insulating material a variety of substances may be used. Crumpled or shredded newspaper, sawdust, cotton-seed hulls, ground cork (such as is used in packing Malaga grapes), wool, Spanish moss, hay, straw, and excelsior may be used satisfactorily (Figure 10, *B*).

It is safer to pack the container with some non-inflammable material, such as asbestos. A cheap and easily obtained substitute is small cinders sifted from soft coal ashes, which may be obtained at the boiler house of any mill if soft coal is not used in your home. (Cinders from hard coal are not quite so good but will serve.) Experiments with soft coal cinders made by home economics specialists for the United States Department of Agriculture showed that this material is very nearly as satisfactory for packing as crumpled or shredded paper.



Courtesy of U.S. Department of Agriculture.

FIGURE 10. — LONGITUDINAL SECTION THROUGH FIRELESS COOKER

Showing details of the construction: *A*, outside container (wooden box, old trunk, etc.); *B*, packing or insulating material (crumpled paper, cinders, etc.); *C*, metal lining in nest; *D*, cooking kettle; *E*, soapstone plate, or other source of heat; *F*, collar to cover insulating material; *G*, pad or cushion for top; *H*, hinged cover of box or container.

The Metal Nest. — The insulating material is packed solidly into the container, as will be described later, so as to fit snugly about the metal nest (Figure 10, *C*). This nest should be of a trifle greater diameter than the cooking vessel and deep enough to hold a hot brick or soapstone (Figure 10, *E*) under the cooking vessel. A galvanized iron bucket may be used as a metal nest. Better still, a tinsmith can make a galvanized iron can of the required size, with straight sides, a rolled rim, and a flat cover (Figure 11, *A* and *C*).

Flange or Collar to Cover Insulating Material. — Have the tinner cut a sheet of galvanized iron exactly to fit the opening of the container. It should fit so closely in length and breadth that it will just slip into the container so as to cover the contents completely. In the center of this metal sheet cut a hole just large enough to allow it to be slipped over the bottom of the metal nest and fitted up snugly under the rolled rim as a collar for the metal nest (Figure 11, *D*). When the nest is put in place, the collar (Figure 10, *F*) covers the packing, and serves the important purpose of keeping it dry.

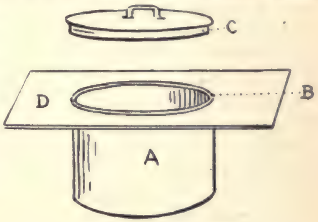


FIGURE 11.

A, metal nest, with rolled rim, *B*; *C*, cover; *D*, detachable collar or flange.

The Cooking Vessel. — This should be durable and free from seams and crevices, which are hard to clean. It should have perpendicular sides. The cover should be as nearly flat as possible and should be provided with a deep rim extending well down into the kettle to retain the steam. It is possible to buy kettles made especially for use in fireless cookers; these are provided with covers which can be clamped on tightly.

Tinned iron kettles should not be used in a fireless cooker, for although cheap they are likely to rust from the confined moisture. Enameled ware kettles, with covers of the same material, are satisfactory. Aluminum vessels do not rust, and they may be purchased in shapes that are especially well adapted for use in fireless cookers.

To Pack the Box or Container. — Line the bottom of the box, and the sides to within four inches of the top, with 10 or 12 sheets of newspaper or wrapping paper, with several thicknesses of cardboard, or with sheet asbestos $\frac{1}{8}$ inch thick. Use a few tacks to hold the lining in place. Shred newspaper into bits and cover the bottom of the box evenly and compactly with the shredded

paper to the depth of four inches. Cover this with one or two thicknesses of sheet asbestos $\frac{1}{8}$ inch thick. (If non-inflammable packing material is used, this asbestos cover for the lower four inches of packing is not needed.)

Wrap the metal nest with a sheet of the asbestos paper, and stand it, *without the collar*, on top of the packing, in the center of the box. Pack more shredded paper, or whatever insulating material is being used, all around the nest as solidly as possible, until it reaches the rim of the metal nest. The top of the packing material and the rim of the nest should now be about four inches, or more, below the cover of the box.

Carefully remove the metal nest, slip the galvanized iron collar over the bottom of it, and slide it up until it rests just under the rolled rim of the nest. Cut a piece of sheet asbestos of the same shape as the collar and fit it just under the collar. Now replace the nest carefully, and the collar with the asbestos lining under it will cover the packing completely.

Cushion or Pad. — A cushion or pad (Figure 10, *G*) must be provided to fill completely the space between the collar or flange and the cover of the box. This should be made of some heavy goods, such as denim, and stuffed with asbestos fiber, cotton, shredded paper, or excelsior.

A heavy but very efficient pad may be made by tying or quilting newspapers together that have been cut to fit the top space, and covering this paper pad with denim. The pad should be exposed to sun and air whenever it is not in use.

To Use the Cooker. — A fireless cooker is best suited to those foods which require boiling, steaming, or long slow cooking in a moist heat. The classes of food best adapted to the cooker are cereals, soups, meats, vegetables, dried fruits, steamed breads, and puddings. Less water is needed than when foods are cooked on the stove, because there is practically no escape of moisture from the cooking kettle.

To cook food, bring it to a boil on the stove, and at the same time heat the brick or soapstone. Transfer the heated plate to the nest, close the cooking kettle tightly, and place it on the heated plate

in the nest. Cover the nest, lay on the pad, close the box, and fasten the hasp. Allow the food to remain *undisturbed* in the cooker for six or eight hours.

Selected recipes for preparing food to be cooked in the fireless cooker may be found in Farmers' Bulletin No. 771, "Homemade Fireless Cookers and Their Use."

Leave the cooker open when it is not in use.

PROJECT XXI. — *How to Make a Cheap Ice Box*, page 92

The fireless cooker described in Project XX may very readily be used as an ice box for keeping milk (or any other food that may be put in an inclosed vessel) at a low temperature. Simply put the bottle of milk tightly sealed or corked into the middle of the nest and pack ice solidly around it up to the neck of the bottle. Close the lid and keep the box in as cool and shady a place as possible.

A much better and safer plan, if you wish to continue the use of the fireless cooker for an ice box, is to obtain a covered bucket tall enough to hold a milk bottle and of a diameter that will allow about an inch of air space all around between the bucket and the metal nest. Pack the bottle in this with crushed ice, place the bucket in the nest, and close up the box. The double advantage of this is that the air space between the bucket and the metal nest gives extra insulation against the heat, and the bucket may be more easily taken out once a day, emptied of water, washed with soap and water, and sunned.

If the milk, or other food, is cold when it is put into the cooler, it will keep safely for 24 hours. If the food is warm, or the weather is exceptionally hot, the food may require re-icing at the end of 12 hours. Much depends on the care you have exercised in constructing your box. If ice is not obtainable, very cold well water is the best substitute. Put the milk bottle or other closed container into the bucket and fill the bucket almost to the top with cold water. Change the water every twelve hours.

If you have not made a fireless cooker in accordance with the

specifications of Project XX, a still simpler contrivance is suggested by the Chicago Department of Health. Obtain a covered bucket tall enough and wide enough to hold two quart bottles of milk. For a nest get a still larger bucket that will allow about an inch of insulating air space all around between the nest and the inside bucket.

To hold this, a covered box at least 14 inches square and 15 inches tall will be needed. Hinge the cover, put a hasp on it, and cleat

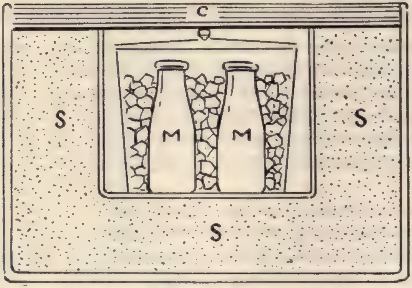


FIGURE 12.

M, milk in sealed bottles, packed in ice in covered bucket; *S*, sawdust packing around nest; *C*, hinged cover with newspapers cleated to it.

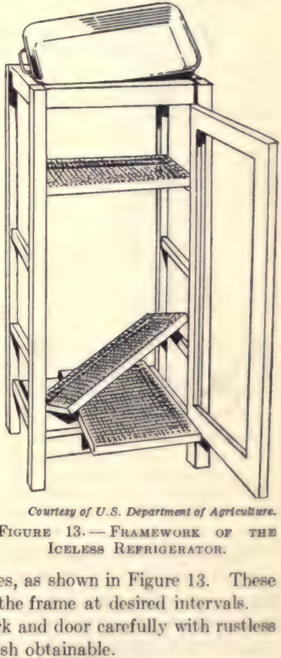
to the inside of the cover about fifty thicknesses of newspaper, so trimmed that the cover will close tightly. Cover the bottom of the box with three inches of sawdust, lay the nest in the center of the sawdust area and pack sawdust to the top of the nest. A vertical cross section of this box is shown in Figure 12. Use the box as directed in the preceding paragraphs.

The principle that explains both the fireless cooker and the ice box here described is that a non-conductor of heat is interposed between substances of different temperatures, thus preventing them from equalizing those temperatures.

N.B. If a tinned iron bucket is used, put a little soda into it each day when the ice is packed. This will tend to prevent rusting.

Project XXII. — *How to Make an Iceless Refrigerator*, page 104

A very useful device for the home where ice is not easily obtainable is the iceless refrigerator (Figures 13 and 14). In farm homes where large amounts of milk and butter are to be kept, it pays to have a separate cooler for these delicate foods, in order to keep them from absorbing odors. The following directions for making such a cooler contain suggestions taken from bulletins of the United States Department of Agriculture.



Courtesy of U.S. Department of Agriculture.

Figure 13. — Framework of the Iceless Refrigerator.

Make a stanch wooden frame for a case 42 inches tall, with the other dimensions 14×16 inches (Figure 13). Make a solid floor and top for the case, with matched boards if possible. The solid top should be set below the top of the framework, so as to furnish an insert to hold the tapering base of a 14×16 inch biscuit pan (Figure 13). Fit a full-length doorframe to the case as in Figure 13, and mount it on brass hinges. Be sure that the door fits closely enough to be fly-proof.

Shelves may be made of poultry netting on light wooden frames, as shown in Figure 13. These shelves rest on side braces set in the frame at desired intervals.

Now cover the entire framework and door carefully with rustless wire screening of the smallest mesh obtainable.

Provide a 17×18 shallow bread pan in which to stand the entire case after it is finished.

Give the framework, screening, shelves, and top and bottom pans two coats of flat white paint. Give plenty of time for drying between coats. When the flat paint is thoroughly dry, apply two coats of white enamel. Remember that the success of enameling a surface depends largely on allowing sufficient time for drying between coats.

Courtesy of U.S. Department of Agriculture.
FIGURE 14. — THE COMPLETED ICELESS REFRIGERATOR.

Before applying the second coat of enamel, be sure that the first coat has lost all trace of stickiness. The amount of time necessary between coats depends on the condition of the atmosphere. It may be several days before you can apply the last coat. Remember that you want a hard enamel surface, and the only way to produce it is to exercise enough patience to allow thorough drying between coats of paint and enamel, and a final thorough drying before the cloth cover is attached to the frame.

A covering of canton flannel, burlap, or duck should be cut and hemmed to fit the case, as in Figure 14. If canton flannel is used, have the smooth side out. About three yards of material are needed. This covering should extend down to the very bottom of the case.

Button the cover around the top and bottom of the frame with buggy hooks and eyes. Another way to button the cloth to the frame is to sew large buttons firmly to heavy strips of cloth at desired intervals, and then tack these strips to the edges where the cover is to be buttoned. On the edges of the covering provide buttonholes at intervals corresponding to intervals between buttons on the strips.

Arrange the covering so that the door may be opened without unbuttoning the edges of the covering. In order to do this, the cover on the front of the case must be buttoned to the top and bottom and latch panel of the door, as shown in Figure 14. Another row of buttons fastens the other vertical edge of the covering to the framework at the opening of the door. Make sure that the hems on these vertical edges are extended far enough to cover the crack between the frame and the closed door.

Sew to the top edge of each side of the covering a double strip of the same kind of cloth. Make these strips long enough to extend about 3 inches into the biscuit pan on top of the case, and taper these strips to a width of 8 inches.

Keep the upper pan filled with water. The strips of cloth serve as wicks to supply the sides of the covering with moisture (Experiment 97, p. 325). The lower pan is to catch the drippings from the covering. A small amount of water in the lower pan also serves the excellent purpose of keeping ants and other insects from the refrigerator. The only inconvenience about the operation of the refrigerator is that the wicks attached to the door must be wrung dry whenever it is opened.

Put the refrigerator in a shady place where the air circulates freely. On dry hot days a temperature as low as 50° F. may be obtained in one of these coolers. When the air is full of moisture, the refrigerator will not work so well. Explain this. On such days more water will drip into the lower pan.

Project XXIII. — *How to Make a Substitute for a Vacuum Bottle*, page 92

A very serviceable substitute for a vacuum bottle may be made of a three-pound coffee-tin, a small amount of asbestos insulating cement (such as is used to cover steam boilers and steam pipes), a yard of cheesecloth, and a bit of flour or library paste, two or three old newspapers, and a Ball-Mason quart jar (Figure 15).

A Ball-Mason quart jar measures 7 inches in height and 3 inches in diameter at the base. An ordinary 3-pound coffee-tin is about

2 inches greater in diameter and a little over 2 inches greater in height. This tin serves as the outside container. If such a tin cannot be had, procure a covered tin bucket of as great, or greater, dimensions.

Mix enough water with the asbestos insulating cement to make a plastic paste. Cover the bottom of the tin with an inch of this paste (*A*). Now mold up a wall of asbestos (*WW*) of even thickness, so as to form a well or nest 7 inches deep and scant 4 inches in diameter.

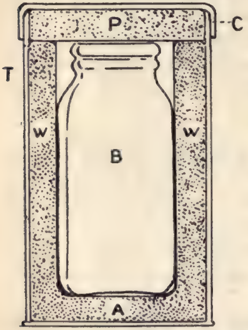


FIGURE 15. — CROSS SECTION OF INSULATED BOTTLE.

T, tin container; *A*, asbestos insulation for bottom of tin; *WW*, asbestos wall; *P*, insulating pad; *B*, Ball-Mason jar; *C*, cover for tin.

When the asbestos cement is dry, line the well and cover the top of the asbestos wall with cheesecloth. This may be pasted on with flour paste, rice paste, library paste, or paper-hanger's paste. The latter may be bought in small cartons at any paint store.

When the jar (*B*) is placed in the well, the top of the jar should be even with the top of the asbestos wall, and there should be an open space of a little more than an inch below the cover of the can. To fill this space, make a newspaper pad. Cut circular pieces of newspaper to fit the space, until you have enough to make a pad of sufficient thickness to fill the space (*P*). Quilt them together and cover the pad with denim.

An insulated jar made in this way will keep liquids hot or cold for 10 or 12 hours. A pint jar may be insulated in a smaller container, if preferred.

There are several reasons why a Ball-Mason jar is superior to an ordinary bottle in the device described: it may be tightly sealed; it is less likely to break when filled with hot liquids; it

has a large mouth and may be easily washed and sterilized; if it breaks, a duplicate may easily be had.

An insulated bottle may be made by using a round cardboard cereal carton for an outside container, newspaper for nest and pad, and an ordinary wide-mouthed bottle with a tight cork for a liquid container. Before pouring hot liquid into such a bottle, be sure to heat the bottle by submerging it in cold water and bringing the water to a boil (pp. 65 and 66).

PROJECT XXIV. — *How to Humidify Indoor Air in Winter*, page 107

The air in kitchens and bathrooms is generally plentifully supplied with moisture. Other heated rooms ordinarily require the addition of considerable moisture to the air.

In case a room is heated by *stove*, keep a pan of water continuously on the stove.

Modern *hot-air furnaces* are furnished with water pans to supply moisture to the air. If your furnace has no such moisture supply, you will have to contrive a humidifier best suited to your needs. Where floor registers are used, it is sometimes possible to set a pan just under the grating and keep it filled with water. If this cannot be done, it may be necessary to adapt the principle illustrated in Figure 53 of the body of the book to a humidifier, which may be put in some inconspicuous place in the room. Of course, the nearer it can stand to the warm air draft, the more rapidly the water will evaporate.

For rooms heated by *steam* or *hot water*, have a tinsmith make a galvanized iron water can of the general shape indicated in Figure 16. The length, breadth, and thickness of the can will depend on the amount of space available between the wall and the radiator. At most it need not have a capacity of more than 2 gallons.

On one of the broad faces of the can solder two No. 10 galvanized iron wires, as shown in Figure 16, *AA*. Curve the ends of these wires so as to hang them over the connecting rod of the radiator as means of support. The distance between the wires must be such

that the weight of the can will be well balanced and each wire will fall between two coils of the radiator.

Bend two No. 15 galvanized iron wires, or a strip of galvanized iron $1\frac{1}{2}$ inches wide, as indicated in Figure 16, *BB*. These should be long enough to have the ends securely soldered to the narrow sides of the can and to extend at least 6 inches above the mouth of the can.

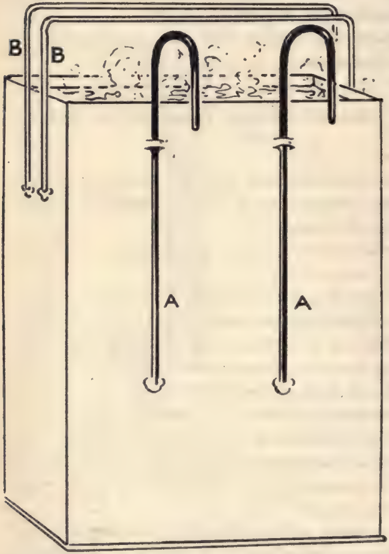


FIGURE 16.—HUMIDIFIER FOR STEAM OR HOT WATER RADIATOR.

Fill the can with water. Over the rack (*BB*) hang a double thickness of canton flannel, rough side out, with the ends of the cloth extending down into the water to the bottom of the can. Suspend the can by the curved wires to the rear of the radiator. The canton flannel will absorb the water from the can (see in this connection Project XXII and look up Experiment 97, p. 325), and the heat from the radiator will cause rapid evaporation from the cloth wicking as well as from the surface of the water in the can. Be sure to keep the can supplied constantly with water. It will probably need attention at least once a day.

PROJECT XXV. — *How to Operate a Refrigerator*, page 111

In operating a refrigerator, there are four things to be kept constantly in mind: it should have a steady temperature of 50° F., or less; it must have a steady circulation of air, as shown in Figure 58 of the body of the book; it must remain dry; it must be kept spotlessly clean.

Low Temperature. — The low temperature of a refrigerator does not necessarily destroy germs; it prevents their multiplying. If food is in good condition when it is put in an efficient refrigerator, it will remain in good condition. Before you buy a refrigerator, be sure that it will maintain a sufficiently low temperature. If the walls are properly insulated in the first place, the joints tight and secure, and the doors tight-fitting and proof against warping, the refrigerator will remain efficient for years.

To maintain low temperature: (1) Keep the ice compartment *full* of ice. Incidentally it is cheaper to do this than to maintain a low supply. (2) Keep drinking water in a covered jar, instead of opening the ice compartment frequently to chip off ice. (3) Do not leave any refrigerator door open a second longer than necessary. If you are removing food that is to be replaced in a few seconds, close the door in the meantime.

Test the temperature of your refrigerator occasionally with a thermometer. Leave the thermometer on each shelf in succession for several hours. If the temperature is much above 50° F., examine carefully the joints, doors, and locks for faulty insulation. Also see that the drain pipe is clean, and that nothing is interfering with the circulation of the refrigerator. If nothing can be done to keep the temperature low in your refrigerator, the safest and cheapest plan is to buy a new one. An epidemic of intestinal disease in a well-known New York hospital a few years ago was traced to inefficient refrigerators.

Air Circulation. — The air circulation explained and illustrated on page 111 of this book is of vital importance. It keeps the interior of the refrigerator at a fairly even temperature and helps to keep it dry. Moreover, the circulating air collects the odors

and impurities and deposits them on the ice, whence they are carried out by the melting ice through the drain pipe.

It follows, therefore, that delicacies, such as milk, cream, and butter, should be put where the air fresh from the ice strikes them. Meats and other such foods should come next. Vegetables, fruit, cheese, fish, or any other foods that emit strong odors, should be last in the circulatory system, so that the odors will be deposited on the ice without tainting the more delicate foods. Even with this arrangement, all highly odorous foods should be kept covered. Two or three pieces of charcoal scattered through the refrigerator and changed two or three times a month will help to absorb odors. Large cafés have a separate refrigerator for each kind of food.

Do not stuff any shelf so full of foods as to impair the circulation of air. As soon as the circulation of cold air is cut off, the temperature of the refrigerator rises and moisture collects — two conditions favorable for germ life.

Do not put any kind of food on the ice. It may impair the circulation of air; but more important than this, it will gather the odors and impurities that should be deposited on the ice.

Dryness. — Keep a little salt in an open dish in your refrigerator. If this becomes damp or sticky, examine your refrigerator, as has been suggested in the case of too high temperature. High temperature and dampness generally go along together in a refrigerator.

Foods that you wish to keep moist or liquids that you wish to keep from evaporating should be kept in tightly covered vessels.

Cleanliness. — Keep your refrigerator spotlessly clean. A porcelain enameled lining without joints or seams is most satisfactory and safest. Don't allow a single drop of milk or speck of food to remain on the shelves of your refrigerator, as breeding places for germs. Keep the interior wiped out with water clean enough to drink and a cloth or sponge clean enough to wash your face with. Wipe all milk bottles, especially the caps and tops, with a clean damp cloth before putting them into the refrigerator.

Once a week wash the interior with soap and water, wipe it out with clear water afterwards, and dry it with a dish towel. Cleanse the ice compartment and flush the drain with a strong solution of

washing soda. After cleaning the refrigerator, replace the ice and close the doors for a while before replacing the food. An iced refrigerator dries much more quickly with the doors shut than an un-iced refrigerator will dry with the doors open.

PROJECT XXVI. — *How to Install Devices for Ventilating*, pages 113–114

Full instructions are given on pages 113–114 for making ventilating boards and screens. Measurements must depend on the size of the window to be fitted.

In the case of cloth screens, the simplest way to get measurements is simply to duplicate the frame of the summer screen and then substitute muslin for wire screening.

PROJECT XXVII. — *How to Siphon Cream from a Bottle of Milk*, page 119

To remove cream from a bottle of milk with a spoon or patent cream dipper is a difficult and often a wasteful operation. The cream or top milk may be much more easily and effectively removed with a glass siphon.

Bend a piece of glass tubing in the laboratory into the form of a siphon (Figure 17). Have the two arms of the siphon close enough together so that the loop may be inserted in a milk bottle as shown in *A*, Figure 17.

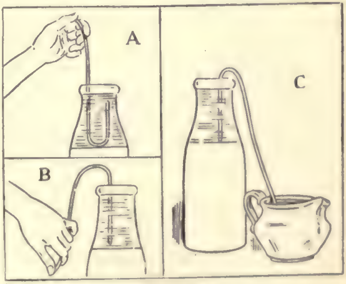


FIGURE 17.

To start the action of the siphon, dip the short arm of the siphon into the cream, as in *A*, Figure 17, allowing the cream to run in and fill the short arm, and the long arm to the depth of the short arm.

Now hold the thumb over the opening of the long arm and place the siphon in position, as in *B*, Figure 17.

Adjust the end of the short arm to whatever depth you wish, place a receiving vessel under the opening of the long arm, and remove your thumb from the opening of the long arm (Figure 17 *C*).

The siphon may be cleansed by running warm (not hot) soapy water through it and rinsing with clear warm water.

Project XXVIII. — *How to Use the Most Common Solvents to Remove Stains*, page 140

Gasoline. — This is the most common solvent for sponging out grease or oil stains. The most delicate fabrics may be soaked or washed in it without risk. It should be used either out of doors or in a well-ventilated room, without flame or smoldering spark of fire or even a hot iron in the room. Never use a hot iron on goods cleaned with gasoline until the fabric has been hung out long enough for all the gasoline to evaporate.

After using gasoline, give the fumes plenty of time to pass out before you light any sort of fire. Remember it is the volatile vapor of gasoline that is so dangerously inflammable.

To remove grease from delicately colored fabrics, chloroform, ether, and benzine are superior to gasoline because they evaporate more rapidly and are less likely to leave a "ring." Chloroform and ether are the best, but also the most expensive.

Probably the best fabric for applying stain solvents is *clean cheesecloth.*

Gasoline is sometimes mixed with carbon tetrachloride, another effective solvent of grease, and sold under a trade name such as "Carbona." The great advantage of such a mixture is that its vapor is not inflammable.

Turpentine. — (1) Paint and Varnish. — Turpentine will remove wet paint or varnish very easily from any fabric. If used with sufficient patience and perseverance, it will also remove dry paint from any fabric. After the paint is removed, sponge with chloroform

to remove the turpentine. Alcohol followed by chloroform, or chloroform alone, will often remove paint or varnish from delicate fabrics.

(2) Tar or Wagon Grease. — Rub lard into the stain to soften it. Wet with turpentine. Gently scrape off all loose particles with a knife. Wet again and again with turpentine and continue to scrape until all loose particles have been removed. Then sponge with turpentine and rub gently with a clean cloth until the fabric is dry. Sponging with chloroform will remove the turpentine and restore the color if it is affected.

For such stains on white wash goods, rub lard on the stain, wet with turpentine, and after several hours wash with soap and warm water. On heavy goods use a brush.

(3) Vaseline. — If sponging with turpentine fails, try sponging with ether.

(4) Hardened Paint Brushes. — (*a*) Soak for 24 hours in *raw* linseed oil. Rinse in hot turpentine. Repeat, if necessary.

(*b*) Heat vinegar to the boiling point and allow the brushes to stand in it.

(*c*) Soak the brushes in paint and varnish remover, which may be bought at any paint store.

N. B. — Brushes should never be allowed to dry hard. They should be kept suspended — never resting on the bristles — in raw linseed oil. A good way to suspend brushes is to bore small holes through the tips of the handles, thread them on a wire stretched between two nails and allow the brushes to be submerged in the oil to a depth of at least ½ inch above the ferrule or binding strap.

Project XXIX. — *How to Prevent Tea-kettle Scale*, page 144

If a tea-kettle is given the daily attention that any other kitchen utensil or cooking vessel receives, there will be no accumulation of scale. Tea-kettle scale is unsightly but in no wise harmful. The principal reason why it should not be allowed to accumulate, or should be removed if it is allowed to accumulate, is that it causes such a waste of fuel. This is not noticeable if the kettle is set all day

over a coal fire, but the waste is considerable if measured gas is the fuel used. It has been estimated that certain kinds of scale offer from twenty to fifty times the resistance to heat that is offered by an equal thickness of wrought iron.

If the tea-kettle is washed daily, or even three times a week, and scoured if necessary with Bon Ami or Old Dutch Cleanser, scale will not accumulate.

Housekeepers who will not exercise this care, may put a piece of limestone, rough marble, or oyster shell in the tea-kettle. Change it for a fresh piece two or three times a month.

Project XXX. — *How to Remove Tea-kettle Scale*, page 144

Heavy Iron Kettles. — To remove accumulated scale from a heavy iron kettle, fill the kettle with cold water and add a heaping tablespoonful of sal ammoniac. Bring this to a boil and then empty the kettle. Place the empty kettle over a flame until it is very hot and the scale will peel off. Set the kettle aside and allow it to cool slowly. Repeat if necessary. After the scale has been removed and the kettle is cool, fill it with a strong solution of washing soda, boil, and rinse with clear hot water.

Aluminum Kettles. — In the case of an aluminum kettle, fill with cold water, and add a heaping tablespoonful of oxalic acid crystals. Boil the solution, let it stand all night, and boil again in the morning. This will remove a thin scale, but the operation will have to be repeated several times for a heavy scale. Afterwards wash the kettle thoroughly with ordinary soap and warm water and rinse with clear hot water to remove all trace of the poisonous acid.

Concentrated nitric acid will remove the scale from aluminum much more quickly than oxalic acid, without injuring the aluminum. But it has to be handled so carefully that it is not recommended for ordinary household use.

Strong alkalies dissolve aluminum. Never use them on that metal for any purpose.

Enamel Kettles. — Scale does not tend to accumulate so rapidly

on good enamel ware. Keep an enamel kettle clean by washing it, or boiling it if necessary, frequently with a strong solution of washing soda. Either oxalic acid or nitric acid will remove scale from enamel ware without "eating" through the enamel, but any strong acid will remove the high polish from the surface of enamel.

Project XXXI. — *How to Soften Hard Water for Domestic Use,* page 146

Water of temporary hardness does not offer a serious problem because it can be softened by boiling. Permanently hard water requires something more to soften it.

For Laundry Use. — Washing soda is the most common softener for laundry purposes. The two mistakes commonly made in its use must be guarded against: do not make too strong a solution; and be sure that the soda is thoroughly dissolved. A failure to observe these cautions may result in injury to the clothes.

Dissolve 1 pound of washing soda in a quart of hot water. For most hard waters, 2 tablespoonfuls of this solution will soften a gallon of water. If the water is unusually hard, more of the solution will be required.

For Delicate Fabrics. — Borax is much to be preferred to washing soda as a water softener because it will do no injury either to the hands or to delicate fabrics. It is so expensive, however, that it cannot be used in great abundance. To soften water for washing delicate fabrics, dissolve 1 tablespoonful of borax in a cup of hot water. This will soften a gallon of water.

For Toilet Purposes. — (*a*) Borax used as suggested in the preceding paragraph will soften water satisfactorily for toilet uses.

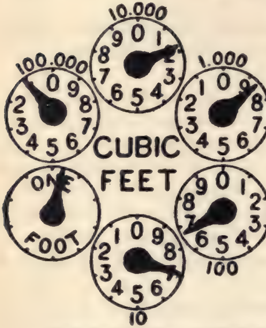
(*b*) The addition of the juice of one or two lemons to a bowl of hard water softens it agreeably for washing or rinsing the hair.

Project XXXII. — *How to Read a Water-meter or Gas-meter Dial,* pages 200–206

Water is sometimes sold to the consumer at a flat rate by the month or year. In such cities there is no direct measurement of

the amount of water a consumer uses. In other cities water is sold at so much per 1000 gallons, and the quantity used by each consumer is measured by a meter on the consumer's premises. Water-meters are pretty accurate instruments. If they are out of order, they are most likely to record less water than is actually used.

It is convenient to know how to read the dial of your water-meter. If it is a direct-reading dial, no instruction is needed. Most water-dials, however, are like the dial shown in Figure 18, and require some explanation.



Courtesy of U.S. Bureau of Standards.

FIGURE 18. — DIAL OF WATER-METER.

On this dial the unit of measurement is the cubic foot. The hands revolve about circles. The numbering on each circle indicates the direction the hand of that circle travels. On the dial shown in Figure 18, the hands in the 100,000, 1000, and 10 circles travel contrary to the hands of a clock. The alternate hands travel in the direction of clock-hands.

The number on the outside of each circle indicates the number of cubic feet recorded for one *complete revolution* of the hand. Each circle has 10 divisions; each division thus indicates $\frac{1}{10}$ of the total for the circle. (In reading the dial, pay no attention to the circle measuring 1 foot. It is used for test purposes, as will be explained later.)

The reading of the dial in Figure 18 is as follows:

1st hand shows $\frac{1}{10}$ of	100,000, or	10,000 cu. ft.
2d hand shows $\frac{1}{10}$ of	10,000, or	1,000 cu. ft.
3d hand shows $\frac{8}{10}$ of	1,000, or	800 cu. ft.
4th hand shows $\frac{6}{10}$ of	100, or	60 cu. ft.
5th hand shows $\frac{7}{10}$ of	10, or	7 cu. ft.

Caution. — Notice that when a hand is between two figures, the lesser is read, just as in the case of the hour-hand of a clock. If the hand is very near a figure, and you do not know whether it is just short of the figure or just past the figure, the following circle will guide you. For example a careless observer might read the 2d circle 2000. If it were 2000, then the hand in the 3d circle would have reached 0 or passed it. Since the hand in the 3d circle has not quite reached 0, the 2d dial-hand is to be read 1000 instead of 2000. In other words, think of the dial hand which shows a doubtful reading as the hour-hand of a clock, and the dial-hand of the following circle as the minute-hand. If the "minute-hand" has completed a revolution and points to 0 or beyond, read the figure toward which the "hour-hand" is pointing. If the "minute-hand" has not quite reached 0, read the lesser figure preceding the "hour-hand."

It can be seen that a quick way to read the dial is to begin with the 10 circle and put the figures down in reverse order. Thus, the 10 circle records units, the 100 circle tens, the 1000 circle hundreds, etc.

Commercially, one cubic foot is equal to 7 gallons, and so if you wish to reduce cubic feet to gallons, multiply by 7.

The dial cannot be set back to 0 after reading. The record is continuous. To ascertain the amount of water used in June, for example, you would have to subtract the reading taken on the 31st of May from the reading taken on the 30th of June. You can also ascertain the amount of water used for any single purpose, such as sprinkling the lawn, by taking the readings before and after using the water.

If you suspect that water is being wasted through some leak, close all outlets tight, and observe the circle on the dial marked "one foot." If it continues to move, there is a leak somewhere on your premises, since the meter can register only when water is passing through it.

A *gas-meter* does not record any number of cubic feet smaller than hundreds. Consequently, the last two circles on a water-meter, recording tens and units, are missing on a gas-meter.

The reading on the gas-meter shown in Figure 19 is 79,500 cubic feet. The hand in the first circle presents a fine example of a doubtful reading. It looks as if it might be exactly 80,000 cubic feet. But since the hand in the 2d circle has not quite reached

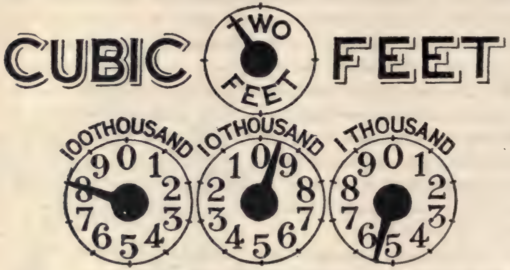


FIGURE 19. — DIAL OF GAS-METER.

zero, the first hand must be read 7 and the second hand 9 — giving 79 instead of 80 thousand.

The circle marked "two feet" is for test purposes, as was explained in the case of the water-meter.

PROJECT XXXIII. — *Learning Weather Lore That a Boy Scout or Camp Fire Girl Ought to Know*, Chapter VIII.

Careful observation of sky and clouds for centuries, of air conditions, and of the behavior of birds, barnyard fowls, and insects, has resulted in a wealth of weather maxims that are pretty reliable. Of course there are many bits of superstition that pass as weather lore that are utterly unreliable. The task for an observer is to sort out weather wisdom from silly superstitions. The most useful and interesting books for the amateur weather forecaster are:

"Official Handbook, Boy Scouts of America."

"Reading the Weather," T. M. Longstreth. Outing Publishing Co.

"American Boys' Book of Signs, Signals, and Symbols," Dan Beard. J. B. Lippincott Co.

"The Wonder Book of the Atmosphere," E. J. Houston. Frederick A. Stokes Co.

" Practical Hints for Amateur Forecasters," P. R. Jameson. Taylor Instrument Companies, Rochester.

"Weather Lore," Richard Inwards.

Study the folk-signs as well as the scientific signs of weather, and report from time to time on the reliability of these signs. Some of the most interesting and trustworthy signs are here given:

Clouds and Sky. — White feathery wisps of clouds, like spreading locks of hair, five or six miles above the earth are cirrus clouds. When these appear suddenly, especially with the ends of the feathers turned upwards, showing that they are falling, they indicate rain to come within two or three days.

Very large low-hanging cumulus clouds (p. 103) indicate violent storms in the immediate future. Such clouds seldom, if ever, appear without an electric display.

When the blue sky is obscured by a delicate veil of white, indicating a thin mist high overhead, rain is indicated. This veil is known as a cirropallium.

Small, dark clouds scurrying along below the big clouds mean rain.

When the sky is overcast with thick, gray clouds with lumpy lower surfaces "like the inverted tops of a pan of buns," a steady rain is indicated.

A pink sunrise indicates fair weather, as does a ruddy sunset. But a ruddy sunrise or a pale yellow morning sky indicates rain. A bright yellow morning sky indicates wind. A great deal of weather wisdom is wrapped up in the old maxim:

"Evening red and morning gray
Will set the traveler on his way;
But evening gray and morning red
Will bring down showers on his head."

Air Conditions. — When all kinds of odors are more noticeable, and smoke descends instead of rising, there are good prospects of rain.

When no dew appears on the grass in the morning, rain is probably indicated.

If raindrops cling to leaves and twigs instead of drying quickly, there will probably be more rain.

Birds and Fowls. — When migratory birds fly south earlier than usual, an early cold winter is indicated.

When birds capable of long flights remain close to their nests, wind and rain may be looked for.

Guinea fowls raise a great clamor before a rain.

Chickens roll and flutter in the dust before a rain.

Crows fly low and wheel in great circles, cawing raucously, before a rain. But if they fly high in pairs, continued fair weather may be expected.

Gulls circle around at great heights, emitting sharp cries as of distress, before a rain.

Insects. — When spiders are seen crawling about more than usual on walls, rain will soon come. This is a reliable sign, especially in the months of winter rains.

When spiders spin new webs or cleanse their old ones, expect fair weather. If they continue spinning during a rain, the rain will soon be over.

When flies or gnats are more than ordinarily troublesome, expect rain or a drop of temperature.

When flies cling to the ceiling or disappear, rain is to be expected.

Project XXXIV. — *How to Remove Stains with Absorbents,* page 325

The principle of capillarity illustrated in Experiment 97 is applied in the removal of stains from the most delicate garments. The use of absorbents, such as blotting paper, French chalk (which is ground soapstone), pipe clay, fuller's earth, common starch, and melted tallow, is the simplest and least risky method of removing grease, wax, blood, and scorch stains.

Mention has been made in Projects IX and XXVIII of the use of absorbents for the removal of ink and tar.

Grease. — (*a*) Cover the spot with fuller's earth, pipe clay, or French chalk. Put a sheet of brown paper over this and press with an iron that is warm but not hot enough to scorch or change the color of goods.

(*b*) Mix a paste of French chalk or fuller's earth with water and place it over the spot. Allow this to stand for several days and then brush it off. Repeat if necessary.

(*c*) Put a piece of blotting paper under the spot and another over it. Put a warm iron on the top blotter. Keep changing the blotters until all the grease has been absorbed. Sponge the spot lightly with chloroform or ether if necessary.

Mud on Delicate Fabrics. — Wait until the mud dries. Gently remove the loose particles. Make a paste of boiled starch. Lay this over the stain and let it dry thoroughly. Brush it off carefully. Repeat if necessary.

Scorch. — Make a paste of boiled starch and use as in case of mud stain.

Blood. — Make a paste of common starch and warm water. Apply it to the stain, allow it to dry thoroughly, and remove by brushing gently.

Wax. — Gently remove all the wax possible from the surface of the fabric with a penknife. Put a piece of brown paper under the fabric. Cover the spot with a paste of starch or French chalk and water. Lay another piece of brown paper over this and press with a warm iron.

Machine Oil on Wash Goods. — Cover the spot with lard and allow it to stand several hours. Wash in cold water with soap.

PROJECT XXXV. — *How to Prepare Soil for Planting a Lawn*, pages 307–339

"The ideal soil for grasses best suited for lawn making is one which is moderately moist and contains a considerable percentage of clay — a soil which is somewhat retentive of moisture, but never

becomes excessively wet, and is inclined to be heavy and compact rather than light, loose, and sandy. A strong clay loam or a sandy loam underlaid by a clay subsoil is undoubtedly the nearest approach to an ideal soil for a lawn; it should, therefore, be the aim in establishing a lawn to approach as near as possible to one or the other of these types of soil." Farmers' Bulletin No. 494, United States Department of Agriculture.

Since one does not choose his home site for the quality of the soil, it is clear that the soil in his yard may not be particularly adapted to the raising of a good lawn. Since the lawn is intended to be a permanent feature of the decoration of the place, it is worth while to do all in one's power to improve the condition of the soil.

If one builds a house and is compelled to haul in soil to fill and grade his premises, he can at least exercise care not to have the wrong kind of filling. If the soil is of excellent quality for lawn purposes, it may be necessary for the owner to guard against having the surface soil covered with subsoil taken from the excavation for the foundation. Never allow soil that is full of bricks, tins, boards, and other building débris to be dumped into your yard even for subsoil. Such débris interferes both with drainage and with upward capillary movement of water in dry weather.

It is almost impossible to grow a lawn of any sort in coarse, sandy soil and it is very difficult to keep a lawn in good condition which has a sandy subsoil. To make a satisfactory lawn where the soil is sandy, add a top dressing of two or three inches of clay and work it into the top four to six inches of sand. If a mixture of loam and well-rotted manure can be laid over this to the depth of two or three inches, a very satisfactory lawn soil will be obtained.

If the soil is too heavy or sour for lack of drainage, mix a layer of sand or finely sifted ashes with the heavy soil, at the same time adding humus to help fertilize as well as coarsen the soil.

Soil should be prepared for a lawn to the depth of 8 or 10 inches, even though the surface seed bed need not be more than 1 inch in depth. In spading a soil that is not deep, be careful not to turn the subsoil over the surface soil. After the soil has been spaded,

rake it fine, then compact it with a lawn roller, and finally loosen a shallow surface bed for the reception of the seed.

Grass should be sowed in the late fall or the early spring. If in the fall, September and October are the favorable months, depending on the time when the fall rains set in. It is not well to do the seeding during a dry period, unless one has at his disposal artificial means for watering. Fall planting has the advantage of allowing a number of weeds to germinate and be killed by the frosts.

In localities where there is low winter temperature and little snow, fall planting is not so successful. In such cases, the soil should be prepared in the fall so as to allow the weed seed to germinate and the young weeds to be killed. Then sow to grass seed as soon as the soil can be broken up in the spring and in time to get the benefit of the warm rains of early spring.

Project XXXVI. — *How to Prepare Soil for the Home Vegetable or Flower Garden*, pages 307–339

Loam is the best garden soil. It needs practically no modification except the liberal addition of manure or artificial fertilizer. As much as 600 pounds of manure a year may be applied with advantage to a garden plot 20 feet square. Coarse manure should be applied in the fall and thoroughly spaded under. In the spring, fine, well-rotted manure should be applied just before spading. This spring spading should work the soil to a depth of 10 or 12 inches. Carefully fine the soil as deep as possible with a rake and smooth the surface for laying off into rows. Tomatoes, eggplants, and other plants that require long growing seasons are materially benefited by an application of well-rotted manure between rows when the plants are about half-grown.

But the back-yard gardener cannot choose his soil. He may have light, sandy soil or heavy compact clay instead of the desirable loam. Much can be done in either case to improve the garden plot. The sandy soil needs the addition of abundant manure to enrich it and to make it more retentive of moisture. If a supply of moisture is lacking, the best substitute is compost. Every gardener

should have a compost heap. . This is a pile of waste organic material prepared from six to twelve months before using on the garden.

In every household there is a waste of garden rubbish, leaves, grass mowed from the lawn, parings and other unused portions of fruits and vegetables. These should all be thrown on the compost heap to decay. Be sure to avoid throwing diseased plants and weeds bearing ripe seeds on the pile. But do not burn your leaves in the fall. Bury them on the compost heap and let them rot for fertilizer. The compost heap should be built in alternate layers of vegetable refuse and earth. Every six or eight inches of organic matter should be covered with an inch or so of soil. The burying helps to rot the vegetable matter. You will find it convenient to make the heap not more than six feet square and about four feet high. It is easier to make the sides of a small pile, such as this, perpendicular and to keep the top flat for the reception and retention of moisture to aid in rotting. If this is forked over once or twice in the late fall and again in the early spring, decay will be hastened. In the spring, spread it on the garden plot like manure and spade it under.

Heavy clay soil may need the addition of sifted ashes from which all clinkers have been removed in order to loosen its texture. Soil that has long been uncultivated or that has been devoted to lawn is likely to be sour. The presence of plantain or sorrel generally indicates sourness. Clay soil because of its compactness and poor drainage is apt to be in this condition. To remedy this, a small amount of some base to neutralize the acid is needed. Apply evenly over the garden plot, when you are preparing the seed bed in the spring, 1 pound of air-slaked lime, 2 pounds of ground limestone, or 2 pounds of unleached wood ashes[1] to every 30 square feet. Rake this into the soil to the depth of 2 inches. Be sure to do this after the spring fertilizer has been worked into the soil, not at the same time. Liberal use of manure and compost helps to loosen clay soil and to make it more workable.

[1] Wood ashes have notable manurial value because of potash salts contained; but lose most of this value if subjected to the action of water (leached).

PROJECT XXXVII. — *How Boy Scouts and Other Campers May Prevent Forest Fires,* Forestry Rules, pages 339–346

Every camper should obtain a copy of the laws of his state regarding the conservation of forests. If a legal permit to build a fire in forests is required of all campers, such a permit should be secured by all means. The following is a copy of the notice posted in forests by the United States Department of Agriculture. It directs attention to United States laws on this subject, and gives a few suggestions that should be heeded carefully.

Forest Fires

The great annual destruction of forests by fire is an injury to all persons and industries. The welfare of every community is dependent upon a cheap and plentiful supply of timber, and a forest cover is the most effective means of preventing floods and maintaining a regular flow of streams used for irrigation and other useful purposes.

To prevent forest fires Congress passed the law approved May 5, 1900, which —

Forbids setting fire to the woods, and
Forbids leaving any fires unextinguished.

This law, for offenses against which officers of the Forest Service can arrest without warrant, provides as a maximum punishment —

A fine of $5000, or imprisonment for two years, or both, if the fire is set maliciously, and

A fine of $1000, or imprisonment for one year, or both, if fire results from carelessness.

It also provides that the money from such fines shall be paid to the school fund of the county in which the offense is committed.

The exercise of care with small fires is the best preventive of large ones. Therefore all persons are requested —

1. Not to drop matches or burning tobacco where there is inflammable material.

2. Not to build larger camp fires than are necessary.

3. Not to build fires in leaves, rotten wood, or other places where they are likely to spread.

4. In windy weather and in dangerous places, to dig holes or clear the ground to confine camp fires.

The fire may be confined in various ways. A circle of stones may be built around the fire, with the draft provided on the side away from the windward. Or, a pit may be dug, and the dirt from the pit cast up in a semicircle to windward, with the opposite side more shallow to provide for draft. If the wind is high, it is wise to clear a space of fifteen or twenty feet in diameter by removing all inflammable material and leaving only the bare earth exposed. Always have several buckets of water at hand to be used in case of accident.

5. To extinguish all fires completely before leaving them, even for a short absence.

"A fire is never out," says Chief Forester H. S. Graves, "until the last spark is extinguished. Often a log or snag will smolder unnoticed after the flames have apparently been conquered, only to break out afresh with a rising wind."

To prevent the re-kindling of a fire after it has apparently been extinguished, pour water over it and soak all the ground around within a radius of several feet. If water is not available, cover the charred remains of the fire completely with earth.

6. Not to build fires against large or hollow logs, where it is difficult to extinguish them.

7. Not to build fires to clear land without informing the nearest officer of the Forest Service, so that he may assist in controlling them.

Project XXXVIII. — *Garden Projects*, pages 366–399

In a manual of this sort, it is not practicable to offer any single garden project, since weather and soil conditions differ so widely

in various regions. Soil conditions may vary greatly even in the same community.

Among the best pamphlets on flower, fruit, and vegetable gardening are those issued by certain wholesale dealers in seeds and by the United States Department of Agriculture. A number of books are listed below, with comments as to their nature and degree of usefulness for beginners.

Vegetables. — "Home Vegetable Gardening," F. F. Rockwell. J. C. Winston Co., 1911.

"The Home Garden," Eben E. Rexford. J. B. Lippincott Co., 1909. These two books are very good guides for the amateur. They deal with vegetable gardening and fruit gardening, furnish useful hints as to the general planning of gardens.

"The Home Vegetable Garden," Adolph Kruhm. Orange Judd Co. Treats of each vegetable separately. Designed for the eastern section of the United States.

"Home Vegetable Gardening from A to Z," Adolph Kruhm. Doubleday, Page and Co., 1918. The same type of book as the preceding, but written with special reference to Pacific Coast conditions.

"Farm Friends and Foes," C. M. Weed. D. C. Heath & Co.

"Home Gardening in the South," Farmers' Bulletin No. 934, United States Department of Agriculture.

"The Farm Garden in the North," Farmers' Bulletin No. 937.

"The City and Suburban Vegetable Garden," Farmers' Bulletin No. 936.

"Control of Diseases and Insect Enemies of the Home Vegetable Garden," Farmers' Bulletin No. 856.

"Home Storage of Vegetables," Farmers' Bulletin No. 879.

Fruits. — "Growing Fruit for Home Use," Farmers' Bulletin No. 1001.

"Making a Garden of Small Fruits," F. F. Rockwell. McBride, Nast & Co., 1914.

"Home Vegetable Gardening" (Part III), F. F. Rockwell. J. C. Winston Co., 1911.

"The Home Garden" (Chapters XIV to XVII), Eben E. Rexford. J. B. Lippincott Co., 1909.

Flowers. — "A-B-C of Gardening," Eben E. Rexford. Harper and Bros., 1915. A very simple and useful book on flower culture.

"Yard and Garden," Tarkington Baker. Bobbs-Merrill Co., 1908. On the care of lawn, flowers, vines, shrubs, and trees. A good all-around book for the amateur.

"Manual of Gardening," L. H. Bailey. Macmillan Co., 1911. A larger book than either of the two preceding. It treats of the care of the lawn, ornamental plants, shrubs, and trees, and devotes a chapter each to the growing of small fruits and of vegetables.

PROJECT XXXIX. — *How to Raise Strawberries without Garden Space*, pages 366–399

It frequently happens in crowded sections of cities that there is no space in yards or near-by vacant lots for any kind of gardening. It is interesting and profitable, therefore, to see what can be done with a flour-barrel — or any other tightly constructed barrel — filled with rich, loamy soil, and placed on a sunlit balcony or in a sunny corner of a paved court.

After the barrel has been filled with good rich soil thoroughly mixed with well-rotted manure, draw circles about the barrel parallel to the top and about six inches apart, beginning with a circle six inches below the mouth of the barrel. On the lines of these circles bore one-inch holes in the barrel, six inches apart. The holes of each succeeding circle should be bored just below the middle of the spaces in the circle above.

In the soil on top and in the holes bored through the sides set strawberry plants. The suggested arrangement of holes gives the maximum of light and air to each of the plants growing from the holes. Two such barrels can be made to supply a good sized family with strawberries in season.

Remember to keep the barrel where it can get the sunlight and be sure to keep it watered. Be sure not to keep it drenched. If water keeps running through the soil in too great abundance and

draining from the hole and from the bottom of the barrel, it will not only wash the loam from the holes and expose the roots of plants, but will also wash the fertility out of the soil.

For careful instructions as to how to raise strawberries, write the United States Department of Agriculture for a copy of Farmers' Bulletin No. 198.

Project XL. — *How to Irrigate a Small Garden*, pages 366–399

Inexperienced gardeners frequently make the mistake, in dry weather, of sprinkling the surface of the soil lightly and frequently. This surface supply of water quickly evaporates. Moreover, this method of watering tends to lure the roots toward the surface instead of making them strike deep, as the roots of hardy plants should strike, into the soil. It is better, either with garden or lawn, to soak a portion of it at a time, possibly taking several days to cover the whole plot, rather than to sprinkle the surface lightly every day.

Where one does not enjoy the convenience of an unlimited water-supply and a garden hose, but has to carry water in buckets to the garden, a very satisfactory system of irrigation on a small plot of ground can be established with the aid of large cans and buckets taken from the tin can pile. Take one-half gallon or gallon cans or even old galvanized iron buckets. Perforate the sides with a hammer and a ten-penny nail. Sink the cans to the level of the ground, about two or three feet apart, between rows of garden stuff.

Fill the cans with water instead of sprinkling the surface of the soil. A gallon of water furnished directly to the roots of plants in this way will do more good than three gallons applied to the surface of the soil.

Project XLI. — *How to Cold-pack a Vegetable — Tomatoes*, page 440

Start with clean hands, clean utensils, and pure clean water.

Use only clean, sound fresh tomatoes. No fruit or vegetable which is withered or unsound should ever be cold-packed. If possible, use only vegetables picked on the day of canning.

Glass jars are much to be preferred to metal cans for home canning. Soft, elastic rubbers of the best grade should be used. Never use old or cheap rubbers. The best are the most economical.

After washing and rinsing the jars carefully, submerge them in a vessel of cold water. Submerge the lids and rubbers in cold water in a separate vessel. Heat the water in these vessels slowly and allow it to boil for fifteen minutes. Allow the jars, rubbers, and covers to remain in the hot water until you are ready to use them. Do not touch the insides of jars or covers with your fingers in the process of packing. Sterilize in the same way all spoons, cups, and other utensils used for packing the tomatoes.

Wash the tomatoes carefully in cold water.

Place them in a cheesecloth bag or dipping basket, and dip them in boiling water. Allow them to remain for $1\frac{1}{2}$ minutes. A shorter period of scalding may loosen the skins; but unless sufficient time is given for scalding, the tomatoes may shrink after packing.

Lift the bag or basket of tomatoes from the boiling water and plunge them into cold water.

Slip off the skins; and if you wish, remove the cores of the larger tomatoes, though the removal of cores is not necessary.

Pack the tomatoes directly into the sterilized jars. Press them down with a sterilized silver tablespoon, but do not crush them. Do not add water. The jar may be filled, however, with the juice of the soft or broken tomatoes.

Add a level teaspoonful of salt for each quart of tomatoes.

Now adjust the rubbers and covers but do not seal them. In the case of jars of the Ball-Mason type, screw the cover on only as far as you can easily screw it with your thumb and little finger. In the case of jars of the "Economy" or vacuum sealing type, place the cover on and clamp it down with the spring. In the case of clamp top jars, put on the cover, lift the wire into place, but do not shut down the clamp. This is to allow for the escape of steam and expanded air during the process of sterilization.

Place in a clean wash boiler a false bottom of wood or metal grating in order to keep the jars off the bottom of the boiler. Better than this, wire cages may be bought at very moderate expense,

which serve to keep the jars off the bottom of the boiler and furnish handles for removing the jars from the boiling water at the end of the process of sterilization.

Put cold or tepid water into the boiler to the depth of two or three inches and place the boiler over the flame. Place the jars in the boiler, and add enough cold or tepid water to cover the jars to a depth of several inches, but not enough to allow the boiling water to reach the covers of the jars.

Cover the boiler and allow the jars to remain in it for *22 minutes after the water begins to boil.*

At the end of 22 minutes of sterilization, remove the boiler from over the fire, take the jars out immediately, and tighten the covers. The clamp-type or the Ball-Mason jars may be inverted a few minutes to test for leakage. The vacuum seal jars should not be inverted. Let them stand until they are cool. If, when the jars are cool, you can lift them from the table by holding to the covers alone, they are probably free of leakage.

For information as to cold-packing other vegetables and as to varying the time of sterilization for altitudes higher than 1000 feet above sea-level, write to the United States Department of Agriculture for a copy of Farmers' Bulletin No. 839, "Home Canning by the One-period Cold-pack Method."

For canning by the cold-pack method in high altitudes, the pressure cooker is very desirable. The increased temperature makes sterilization more certain and hastens the process.

PROJECT XLII. — *How to Cold-pack Certain Berries with Sugar*, page 440

The following particular instructions apply to the cold-packing of blackberries, blueberries, currants, dewberries, black raspberries, and huckleberries, but not strawberries, red raspberries, or gooseberries. For cold-packing other kinds of fruits, see Farmers' Bulletin No. 839, United States Department of Agriculture.

Sterilize jars, covers, rubbers, and all utensils, as directed for cold-packing tomatoes (Project XLI).

If possible, obtain berries picked on the day of canning. Cull, stem, and place them in a clean strainer.

Prepare a medium thin sirup as follows: Into 3 quarts of cold water put two quarts of sugar. When the water has boiled just enough to dissolve all the sugar thoroughly but not enough to make the solution sticky, you have a thin sirup. *To make a medium thin sirup,* continue to boil until the solution begins to thicken and becomes sticky when cooled on the finger tip or on a spoon.

Rinse the berries in the strainer by pouring cold water over them.

Pack directly from the strainer into hot jars with a spoon or ladle. Do not crush the fruit.

Pour the hot sirup over the fruit until the jar is level full and ready to overflow.

Place the rubbers and covers in position *without sealing.*

N. B. *Pack each jar, cover the fruit in it with hot sirup, and adjust the covers and rubbers, before you begin to pack the next jar.*

The operation of sterilizing the packed fruit is exactly the same as in sterilizing the packed tomatoes, except that the berries need be left in the boiler only *16 minutes after the water has begun to boil.*

Remove from the boiler, tighten the covers, and test for leakage.

Store in a dark closet to prevent bleaching. If you have no dark closet, wrap the jars in newspapers.

Project XLIII. — *How to Cold-pack Fruit without Sugar*, page 440

Many excellent housekeepers maintain that the flavor of the fresh fruit is retained better by canning without sugar. In such case, the sugar is added just before serving. For pie filling or salad purposes, fruit cold-packed without sugar is superior to that cold-packed in sirup.

It is almost essential, in canning fruit without sugar, that the fruit be picked on the day of canning. Cull the fruit, stem, seed, or core it, and clean it by placing it in a strainer and pouring cold water over it.

The process of cold-packing without sugar differs from the process of cold-packing with sugar only in two essentials:

1. After the fruit has been packed into the jars, pour *boiling water*, instead of hot sirup, over the fruit until the jar overflows.

2. Leave the packed fruit in the boiler for *30 minutes after the water has begun to boil.*

PROJECT XLIV. — *How to Preserve Vegetables and Fruit by Drying*, page 440

For some city dwellers cold-packing is much to be preferred to the process of drying. Unless you have an oversupply of vegetables and fruits in your own garden, and can thus obtain them absolutely fresh and without extra cost, you will probably find it neither economical nor satisfactory in other ways to experiment with the drying of vegetables.

If, on the other hand, you have an oversupply of vegetables in your own garden that you cannot sell, and you have no jars for cold-packing, by all means dry your vegetables and fruits for winter use or for winter markets. Many people much prefer the flavor of certain dried fruits and vegetables to that of corresponding canned products.

It is hardly profitable to undertake the drying of a fruit or vegetable simply to satisfy one's curiosty. If, on the other hand, an oversupply of garden produce makes drying a practical and economical project, detailed instructions are needed for guidance. Such instructions, differing for each vegetable and fruit, are given in Farmers' Bulletin No. 984, "Farm and Home Drying of Fruits and Vegetables," United States Department of Agriculture.

PROJECT XLV. — *How to Store Eggs for Winter Use*, page 440

Eggs are most abundant and cheapest in spring and early summer. This is the time to store them for winter use. To obtain the most satisfactory results, do not store any but perfectly fresh eggs. Eggs are somewhat like milk; they get their taint not so much from being in storage as from careless handling before they are

stored. They should be kept away from all musty odors and in a cool place from the time they are laid until they are eaten.

The three successful methods of preserving eggs, aside from cold storage, are to varnish them with vaseline, to submerge them in limewater, and to submerge them in a solution of water glass. Of these three methods, the water glass solution is the most satisfactory. It must not be expected that preserved eggs will be as palatable as fresh eggs, but if they are packed fresh in a solution of water glass that is not too alkaline, they will compare very favorably with the eggs that are bought at your grocer's in winter. For cooking purposes they are just as satisfactory as fresh eggs.

Water glass may be bought as a thick sirup. It should be used in the proportions of 1 volume of water glass to 10 volumes of water. Water glass that is too strongly alkaline will make eggs bitter.

To Preserve 10 Dozen Eggs. — Boil 5 quarts of water and allow it to cool. Add one pint of water glass. Put the solution in earthenware crocks or wooden pails that can be covered tightly. Be sure that the receptacles are clean and odorless, and be sure that the eggs are wiped, *but not washed*, clean before putting them in the solution. (Washing removes an outer protective coating from the eggshell.) After the eggs have been put in the solution, small end down, cover the receptacle and put it in a cool place.

If you boil eggs that have been preserved in water glass, run a needle through the shell at the large end. This will prevent the shell from breaking through expansion of the moisture and air inside.

PROJECT XLVI. — *How to Distinguish Fresh from Stale Eggs,* page 440

(*a*) Fresh eggs have a slightly rough coating over the shell.

(*b*) Since an eggshell is porous, an egg loses in time part of its liquid contents by evaporation. This causes the white and yolk to shrink, and the emptied space to be filled with air or some other gas. This air space is generally at the broad end of the egg, and in a good egg should not be larger than a dime.

To Test Eggs by Candling. — Roll a sheet of cardboard into a tube or cylinder, large enough to fit down over a lamp chimney or a candle. A large shoe box with the ends removed and the cover fastened in place will serve as well. In the side of the tube or box opposite the flame, cut a hole somewhat smaller in diameter than an ordinary egg.

Place the tube over a candle, lamp, or incandescent lamp, so that the light is visible through the hole in the side of the tube. Hold each egg to the opening in the cardboard, broad end up, and observe it against the light. In a good fresh egg, the air space is small, the yolk appears clear and round in dim outline, and the white is clear. If the air space is rather large and the yolk is darkened, the egg is stale. If the contents of the egg appear dark or hazy, with a black spot, the egg is unfit for food.

If one has much testing of this kind to do, it is better to secure a candling chimney for a small sum at a poultry store.

(*c*) The loss of liquid content by evaporation makes an egg lighter, and so it may be tested by its specific density (p. 150). Make a solution of one quart of water with two tablespoonfuls of salt. A fresh egg will sink in this solution. A very stale egg will float. Eggs at stages between a very fresh and a very stale egg may float at various depths.

Project XLVII. — *How to Dress a Minor Wound,* pages 444–445

No home, office, or school should be without a Red Cross First Aid Kit.

Do not attempt home treatment for anything but scratches or shallow cuts or punctures. In case of deep cuts, accompanied by severe bleeding, *call a doctor immediately.* Pressure on the wound with a pad of aseptic gauze will retard the flow of blood until the doctor can arrive. Do not use your fingers or an unclean cloth for this purpose.

If the blood comes in spurts, an artery has been cut. In this event, pressure should be exerted, if possible, on the supply artery

between the wound and the heart. The artery can often be located by its pulsations. In case of a severed artery in leg or arm, let the patient lie on his back and elevate the wounded leg or arm. An elastic band, a pair of elastic suspenders, or a tightly wrapped bandage applied between the wound and the heart will often serve to stop the bleeding in 15 or 20 minutes.

In very severe cases, a tourniquet may be used. To make a tourniquet, knot a strong handkerchief or cloth about the arm or leg above the wound, place the knot over the supply artery, and use a stick to twist the bandage as tight as necessary. Such a bandage should not be left on more than 20 minutes. If the doctor has not arrived in that time, exert pressure with a pad over the wound itself for about five minutes and then replace the tourniquet.

In case of deep punctures, such as are made by nails, long splinters, etc., have them cleaned and disinfected immediately by a doctor to avoid danger of lockjaw or blood poisoning.

Never neglect minor incisions, scratches, or punctures. See first that all foreign matter is removed from the wound and from the surface around it. This should be done with a piece of aseptic gauze and carbolic acid solution (1 teaspoonful of carbolic acid or lysol to a pint of water), boric acid, bichloride of mercury solution, turpentine, or grain alcohol. See that the antiseptic solution reaches every part of the wound.

If there is tendency to bleeding, bandage the wound firmly with aseptic gauze. A bandage is also useful to keep the wound from coming in contact with infected surfaces. If the wound is where there is little if any danger of such infection by contact, do not be afraid to leave it open to light and air. This is infinitely better anyhow than binding it with a cloth that is not clean or closing it up with unclean court plaster.

Quick closing of the surface of a wound is not desirable. The healing should be "from the inside out." If inflammation and soreness persist, it will frequently be found that the wound needs to be reopened with a sharp instrument that has been disinfected by dipping it in alcohol or carbolic acid. When the wound has

been opened, cleanse it again with carbolic acid solution, bichloride of mercury solution, turpentine, or grain alcohol.

Do not attempt to reopen or cleanse deep wounds. That is a doctor's work.

Caution. — Do not depend on ordinary peroxide of hydrogen for disinfecting.

Two of the best and simplest books on first aid are:

"First Aid for Boys," Cole and Ernst. D. Appleton & Co.

"American Red Cross Abridged Text-Book on First Aid," P. Blakiston's Son & Co.

Project XLVIII. — *How to Disinfect a Room by Fumigation,* pages 444–445

The most important thing to be done at the outset is to seal the room thoroughly so as to prevent the escape of gas until the process of fumigation is completed. Close all windows and doors, except the door provided for exit, but leave the windows unlocked so that they may be opened from the outside. The temperature of the room should be at least 60° F. or higher. The higher the temperature the better, provided there is no exposed flame in the room.

Make a formaldehyde solution by dissolving 12 ounces of 40% solution of formaldehyde in 1 gallon of water. Soak strips of paper in this solution and paste 4 to 6 thicknesses of them with paper-hanger's paste over all door, transom, and window cracks, over stove-holes, keyholes, registers, or any other openings of any sort. After the strips are in place, wet them thoroughly with a brush dipped in the paste. Large openings may need more than a single thickness of paper. To prevent the skin of the hands from roughening or peeling, grease the hands or put on rubber gloves before handling the formaldehyde solution. The fumes from this small amount of the solution may be disagreeable but they are not dangerous.

Hang clothing, bed covers, and everything that cannot be disinfected by boiling, on lines stretched across the room. Stretch

shades and curtains to full length. Open long seams on pillows and mattresses and set them on edge. Open closet doors, dresser drawers, chests, and trunks. Open books and spread them out. In short, make it possible for the fumes to reach every part of everything in the room.

Now place an ordinary wood or fiber washtub in the center of the room. In the middle of the tub put two bricks on edge as a base for a large bucket.

Before proceeding to fumigate, moisten the air of the room thoroughly by boiling water in the room, by dropping hot bricks into warm water, or by using an atomizer. The first method is the most effective. Remember that a moist atmosphere is essential to effective fumigation. The cloudier the room becomes with moisture the better.

When the room is ready, spread 10 ounces of potassium permanganate (the needle-like crystals, not the rhomboid crystals nor the dust) evenly over the bottom of a 14-quart bucket having rolled, not soldered, seams. Put enough boiling water into the tub to reach almost but not quite to the top of the bricks. Put the bucket on the bricks in the center of the tub. Pour into the bucket 24 ounces of formaldehyde solution. The reaction between the potassium permanganate and the formaldehyde solution is very rapid and formaldehyde is liberated in great quantities. Be sure, therefore, that everything is in readiness for you to beat a hasty retreat and to seal the door of exit, before you pour in the formaldehyde solution. Leave the room sealed for six hours.

Be careful in handling the potassium permanganate. It is likely to stain anything with which it comes in contact. The effervescent action is so violent when the formaldehyde solution is poured on the potassium permanganate that the bucket must be fully as large as indicated. If convenient, have it larger.

The amount of chemicals indicated is sufficient to fumigate a room $12 \times 12 \times 10$. If the room is larger, provide more tubs and buckets. Do not increase the amount of the chemicals for a single bucket. This process can be depended upon. Not all the fumigating candles and advertised apparatus are so reliable.

Even if candles approved by health authorities are used, it is best to use twice as many of them as directed.

Fumigating with Sulphur Candles. — The preparation of the room for fumigation is exactly the same as for fumigating with formaldehyde. For a room 12×12×10, six of the pound candles would be needed, no matter what the directions accompanying the candles may call for. Put them in pans on the table, not on the floor, in the center of the room, fill the water jackets two thirds full, light the candles, leave the room promptly, and seal the exit door. Leave the room sealed for from 12 to 24 hours.

The *advantage* of sulphur fumigation over formaldehyde fumigation is that it kills all insects as well as germs and thus prevents insects carrying the disease.

The *disadvantage* is that the fumes of sulphur tend to bleach and otherwise to impair all kinds of fabrics, and are apt to injure brass, copper, steel, or gilt work.

Note. — An excellent gum for use in sealing the room with newspaper strips is powdered gum tragacanth. Soak two teaspoonfuls of powdered gum tragacanth in one pint of cold water for an hour. Then place the vessel containing the mixture in a pan of boiling water and stir until the gum is dissolved. This seals effectively, washes off easily, and will not stain or discolor woodwork at all.

Project XLIX. — *How to Prevent Dampness in Cellars and Dark Closets*, page 444

Since dampness and darkness are favorable to the growth of bacteria and molds, and furnish inviting conditions for waterbugs, roaches, and other disagreeable insects, modern houses are built as nearly damp-proof and as free from dark corners as possible. In many old-fashioned or ill-constructed houses, there are damp and dark closets and cellar-rooms. To the unpleasantness and unhealthfulness of such corners is added the loss occasioned by rust and mildew.

Permanent removal of these conditions by whatever building alterations are necessary is the most satisfactory remedy, and

in the end it is the most economical. But if you do not own the house, or for some other reason you find it impracticable to make the necessary alterations, conditions may be greatly improved by a simple expedient.

Place one or more earthenware bowls of quicklime in the closets or cellar-rooms. The amount of quicklime will depend on the size of the closet or room. Quicklime rapidly absorbs moisture from the air (p. 141 of this book) and counteracts stale odors common to such places. This drying of the atmosphere lessens the danger of rust and mildew. Moreover, the odor of quicklime apparently repels insects and mice that are likely to congregate in such places.

When the lime becomes air-slaked, substitute a fresh supply. Do not throw the air-slaked lime away; you may find it useful for your lawn or garden (p. 315 of this book; see also Project XXXVI).

Project L. — *How to Pasteurize Milk at Home,* pages 446–447

Choose a covered pail large enough to hold the bottle or jar in which the milk is contained. Obtain a pie tin that just about fits inside the bottom of the pail. Perforate the pie tin and place it, inverted, in the pail. On this false bottom set the bottle, or bottles, of milk, tightly capped or plugged with absorbent cotton. If you buy your milk in bulk rather than in bottle put it in a Ball-Mason jar, sterilized as for canning vegetables (Project XLI). Adjust the rubber, screw down the cap tightly, and put the jar into the pail. Fill the pail with water enough to rise to the neck of the bottle but not to reach the mouth of the bottle. The water should be as warm as possible without being hot enough to break the bottle.

Now cover the pail, put it on the stove, and bring the water to a boil. The minute the water begins to boil, not simmer, remove the pail and its contents from the stove, set it in a place where it will not lose heat rapidly, and cover it with a heavy cloth. Let it so remain for thirty minutes. Then remove the milk bottle from

the pail and cool it as rapidly as possible without breaking the bottle. All possible speed in cooling the bottle is just as important as the preliminary heating. As soon as the bottle is cool enough, put it, still tightly capped, into the refrigerator.

In pasteurizing milk, it is well to raise its temperature to 150° F. in order to destroy the dangerous bacteria, but not to exceed 160° so as to avoid scalding or boiling the milk. The method outlined above accomplishes this as well as it can be accomplished without special apparatus. It might be supposed that more accurate results could be had by inserting a chemical thermometer in the milk itself to test the temperature during the process of sterilization.

But the best authorities do not recommend this procedure for home pasteurization, because the hole for the insertion of the thermometer prevents perfect sealing of the milk during pasteurization and makes contamination possible through careless handling afterwards. It must be remembered that pasteurization kills the bacteria in milk, but it does not eliminate dirt or prevent milk from being contaminated afterward through carelessness. It is important that places where milk is kept should be spotlessly clean; refrigerators especially should be looked after in this regard.

Where milk is to be pasteurized regularly for infants, a home should be provided with one of the commercial pasteurizers, such as the Freeman or the Straus Home Pasteurizer. In these the milk may be subjected to exactly the right temperature for the correct length of time, and then cooled quickly. Moreover, the milk may be pasteurized in the bottles from which the infant takes it. The Straus Home Pasteurizer, invented by Nathan Straus, the great crusader for pure, clean milk, is inexpensive, easy to manipulate, and "fool-proof." Instructions for making and using such a pasteurizer, if one cannot be bought in your community, are given in the following books:

"Disease in Milk; the Remedy Pasteurization," Lina G. Straus. N. Y., 1913.

"The Milk Question," M. J. Rosenau. Houghton Mifflin Company, 1912.

Project LI. — *How to Test the Home Water-supply for Organic Impurities,* page 447

(*a*) In a clean porcelain dish boil one quart of the water to be tested. Continue to boil it until it evaporates.

If what remains in the bottom of the vessel immediately after the water is evaporated is white and powdery, there are probably only harmless mineral substances in solution in the water-supply.

If what remains immediately after the water is evaporated is partly white and partly yellowish or greenish, with gum-like stains around the edge of the residue, the water contains organic impurities of either vegetable or animal origin.

Continue to heat the residue. If the yellowish or greenish or gum-like portions turn black, sputter, and burn away, giving out an offensive smell like burning feathers, the organic matter is pretty certainly of animal origin and is unwholesome if not positively poisonous.

(*b*) Unless you live directly on the seacoast or in a region of salt-bearing rocks, neither the surface nor the underground water-supply should contain more than a minute trace of common salt. Anything more than a trace of common salt probably has its origin in vegetable or animal refuse.

To Test for Salt. — To a tumblerful of the water to be tested, add 20 drops of nitric acid, and a small crystal of nitrate of silver — or 5 drops of a solution of nitrate of silver. Stir with a clean strip of glass. The normal amount of salt will be indicated by a faint bluish-white cloudiness. If the water shows marked cloudiness or a solid curdy substance, too much common salt is present.

The presence of both organic matter and considerable salt indicates that the water is probably contaminated by sewage or stable drainage. The source of pollution should be discovered and removed without delay. In the meantime, none of the water should be used for drinking or cooking without purifying it since such water may contain bacteria dangerous to the health. If there is the slightest doubt about the fitness of water for drinking purposes, it should be treated as directed in Project LII.

Project LII. — *How to Clarify and Purify Water for Home Use*, page 448

Water may be murky in appearance without being unwholesome; on the other hand it may be clear without being pure. But clear water is at least inviting. If a water-filter is used to clarify water, it should be thoroughly cleansed at least once a week — preferably oftener. To remove heavy sediment, where a filter is not used, water may be strained through a flannel bag. Small flannel bags with running strings may be fastened on the faucets. These should be changed daily. Wash the used bags with soap and water and hang in the sun to dry.

Water that contains organic substances may be clarified with the use of alum. The alum coagulates albuminous substances, much as boiling coagulates the white of an egg. This coagulated albumen settles to the bottom and acts like a net in carrying down other impurities with it.

A lump of alum suspended by a string and swung about in a pitcher for a minute or so will clarify it.

A teaspoonful of powdered alum will clarify 4 gallons of water. Stir the water vigorously before adding the alum. Allow the impurities to settle and then draw the water in such a way as not to disturb the sediment. The alum, if there is not too much used, will settle with the sediment.

To purify contaminated water, boil it for 16 minutes. This drives off the air and makes water taste flat. To restore the sparkle, pour the water rapidly from one vessel to another several times. This aërates the water. A few drops of lemon juice add surprisingly to the palatability of boiled water.

Project LIII. — *How Boy Scouts Filter and Purify Water for Drinking*, page 448

The methods applied in the home purification of water may be used by Boy Scouts in field or camp. Run no risks whatever with the water you drink. If you are going for a day's tramp and are

doubtful of the purity of the water you may find, take a canteen of pure water with you.

Chlorine is the substance most commonly used by city water departments in the purification of contaminated water-supplies. Chlorine tablets are sold for home use or for camping trips. Some city health departments furnish them free or sell them at cost to people who plan to spend their vacations camping. The tablets may be used according to directions accompanying them to rid water of all dangerous germ life. They are exceedingly convenient to have, especially when time or means is lacking for the boiling of suspected water. All campers should be supplied with them.

Water from ponds, lakes, or running stream in truly wild regions is generally safe. If water is uncontaminated by *animal refuse*, it will not cause disease, no matter how much decaying vegetation there may be in it. Sometimes the murky water of ponds or even swamps is purer than the clear water of running streams, which may be polluted by careless campers upstream. The murky water of ponds or swamps may be clarified by the digging of an Indian well.

A few feet from the edge of the pond or swamp, dig a hole from 12 to 18 inches in diameter, with the bottom of the hole extending 6 inches below the water-level of the swamp or pond. Let the water seep into it and then bail it out quickly. Repeat this process at least three times. After the third or fourth bailing, the Indian well will be filled with filtered water.

If you are at all in doubt as to the purity of the water, either boil it or use the chlorine tablets as directed.

Project LIV. — *How to Exterminate the Mosquito*, pages 452–454 (Community Project)

This is a community project, except in rural districts where houses are widely separated. But in the city or village it does no good whatever to destroy the breeding places of mosquitoes on your own premises if your neighbors provide favorable conditions for

them either on their own premises or on adjoining vacant lots. In New Orleans, Havana, the Panama Canal Zone, and many other places, intelligent and concerted effort has eliminated the mosquito as an agent of disease. Any community may accomplish the same thing.

In order to fight the mosquito intelligently, we must know something of the way the pest comes into the world. When one realizes that one female mosquito lays from 75 to 300 eggs at a time and that these eggs develop into full-grown mosquitoes in from 10 to 13 days, one does not wonder at the clouds of mosquitoes that sometimes infest low swampy places.

Mosquito eggs are laid at night or in the early morning on the surface of stagnant water. Mosquitoes avoid running water or fresh water that is frequently stirred. In about 24 hours in warm weather — or somewhat longer if the temperature is not high — the eggs hatch into the larva stage. The larva, or "wiggletail," which almost everyone has seen in stagnant pools or rain barrels, spends most of its time, head downward, just under the surface of the water. It keeps the tip of its tail (where the opening of its breathing tube is located) almost constantly at the surface of the water. *In fact, the larva cannot live more than a minute or two if it is unable to reach the surface to breathe.* After seven days or more, according to the temperature, the developing mosquito passes from the larva to the pupa stage. After living in the water in the pupa stage for three days or more, it finally emerges as a full-grown mosquito.

Mosquitoes do not fly far from the places where they are hatched; hence, if they can be kept from breeding near human habitations, the problem of mosquito riddance is solved.

Drainage. — Since stagnant water furnishes breeding places for mosquitoes, the first work to be done is to drain all unnecessary ponds or pools. Very often valuable land may be reclaimed by the very process of draining that rids a section of mosquitoes.

Kerosene. — Where it is impracticable to drain pools, puddles, or marshes, the surface of the water may be covered with kerosene. On small pools or tanks it is necessary only to pour the kerosene

on the surface of the water. It will spread in an even film over the entire surface. On marshes or large ponds, where weeds and intervening dams of mud prevent the film of oil from spreading over the entire surface of the water, it is best to use a sprayer. In either case, use about 1 pint for approximately every 20 square feet of water surface.

This film of kerosene kills all eggs at the surface of the water, suffocates the larva or "wigglers," by cutting off their air supply, and destroys all adult female mosquitoes that try to lay their eggs on the surface of the water.

It takes about a week or ten days for the oil to evaporate from the surface of the water, and at least 10 days after that before a new generation of mosquitoes can be hatched. It is a safe plan, therefore, to apply kerosene to the surface of all stagnant pools about twice a month. In covered tanks, cesspools, etc., one application a month is sufficient, because evaporation does not take place so rapidly from such unexposed places. In heavy soil, cow tracks and other small depressions may hold water long enough to hatch a generation of mosquitoes. After every rain, such depressions should be drained or else sprayed with kerosene.

Fish. — Where pools are used for the watering of stock, kerosene cannot be used, of course. In such cases, the remedy lies in stocking the ponds with top minnows or sunfish. These fish feed on the larva of the mosquito. If there are no other fish in the pond, the top minnow may be used. If the pond is stocked with larger fish, the sunfish, sometimes called "pumpkin-seed," is to be preferred because it is able to protect itself by means of its rays against larger fish. Do not neglect to drain cow tracks around such ponds, or else spray them with kerosene often enough to prevent mosquitoes breeding in them.

Screening. — Water tanks, rain barrels, cisterns, and other receptacles for water for the household cannot be treated with kerosene. Careful screening of all the openings of these receptacles is the only remedy. The only effective screening against mosquitoes is the 16-mesh screen — 16 wires to the inch. No one argues for less than a 14-mesh screen, and most authorities insist on a 16-mesh.

If your house is equipped with screens of larger mesh and you are troubled with mosquitoes that squeeze in between the wires, rub the screens every night before dark with a cloth moistened with kerosene. If you dislike the odor of kerosene, try the more expensive oil of pennyroyal.

Tin Cans as Breeding Places. — A single tin can may catch enough water from a rain to breed a multitude of mosquitoes. Before tin cans are thrown on the rubbish heap, punch them full of holes or knock the bottoms out of them. Tin cans carelessly thrown on vacant lots make a neighborhood look slovenly and furnish homes for immense families of neighborhood mosquitoes.

The following Farmers' Bulletins dealing with the subject of mosquitoes may be had on application to the United States Department of Agriculture, Washington, D. C.:

"Some Facts about Malaria," Farmers' Bulletin No. 450.

"The Yellow Fever Mosquito," Farmers' Bulletin No. 547.

"Remedies and Preventives against Mosquitoes," Farmers' Bulletin No. 444.

Project LV. — *How to Fight the Fly*, pages 454–455 (Community Project)

Fighting the fly is not an individual project; it is a community project. If you live in a small town, you may be able to interest various organizations in the project. If you live in a large city, you may be able to wake up your neighborhood. You can do something and should do everything in your power on your own premises; but coöperation is necessary if the fly is to be conquered.

Boy Scouts, Neighborhood Improvement Clubs, Civic Leagues, Women's Clubs, High School Science Clubs, Commercial Clubs, Chambers of Commerce, and other organizations have succeeded in making some communities almost flyless. The community must be educated to the menace of the fly before anything worth while can be accomplished, and this requires the combined effort of civic clubs. Some day people will wonder that we tolerated such a men-

ace exactly as we wonder at the unsanitary living conditions common centuries ago.

The average life of a fly is about three weeks. Most of the millions of flies that do not die of natural causes during the summer succumb to fungous diseases in the fall or to the cold of early winter. But in almost every house a few survive. They hide in all sorts of warm crevices, where they pass the winter in a state of complete rest. The number of flies that may be descended in one summer from one wintered-over fly runs into the trillions! The moral is: clean and disinfect every crevice of your house in March and swat the wintered-over fly.

Screen all porches, windows, and doors in fly time.

Make all vaults fly-proof with screening, and cover the contents once a week with copperas or iron sulphate to disinfect them and to prevent the development of fly maggots.

Keep all garbage covered tightly until it is disposed of. To kill all flies in and around garbage pails, sprinkle formaldehyde solution — 1 part formalin to 10 parts water — in and around the pails once a week.

Make traps and set them near doors and other places where flies congregate. Patterns and detailed instructions for making an effective fly trap may be had by sending five cents in stamps to the Agricultural Extension Department of the International Harvester Company, Chicago. See also Farmers' Bulletins Nos. 734 and 927.

All flies breed in filth. Ninety per cent of all flies breed in stable filth! This should be hauled away and spread as fertilizer at least once a week. If this cannot be done, keep it in tightly covered boxes or pits until it is removed. Farmers' Bulletin No. 851 gives detailed instructions for the extermination by some means or other of flies that breed in stable filth. See that ordinances are passed and enforced against all people who maintain live stock in a community.

For organizations that wish to conduct a fly campaign, the following books and pamphlets will prove of great value:

"Farmers' Bulletin" No. 851. This treats of the life history of the fly, of its carriage of disease, its natural enemies, control measures,

preventive measures for communities and farms, and directions for community campaigns.

"The House Fly," L. O. Howard. Frederick A. Stokes Co., New York.

"The Reduction of Domestic Flies," Edward H. Ross. J. B. Lippincott Co., Philadelphia.

PROJECT LVI. — *How to Make War on the Rat*, page 454 (Community Project)

Among all mammals, the rat is the worst pest known to man. Individual war against rats on one's own premises is more effective than individual war against flies, but only united effort in communities can achieve permanent results. The loss of approximately 150 millions of dollars a year from the depredations of rats, aside from the menace of disease they offer, is too great a tax for the United States to tolerate indefinitely.

The first thing to do on one's premises is to see that, by means of steel, concrete, and wire netting, all construction is made rat-proof. This applies not only to homes, but also to barns, granaries, poultry-houses, drains, sewers, etc. The saving will more than pay for the extra cost of construction.

Keep all garbage cans tightly covered, and leave no scraps of food of any sort exposed on your premises as a lure to rats and mice.

Trapping is the safest method of dealing with rats that have gained access to buildings, such as homes, stables, warehouses, mills, factories, etc. The baited spring trap may occasionally catch inexperienced young rats, but it seldom fools the wise old ones. Rats are very wary, and they seem to recognize bait by its position as well as by the odor of human hands. Of all traps for the catching of rats, none is so satisfactory as the smallest "Newhouse" game trap. Place unusual food — grain if the rats have been feeding on meat; meat if they have been feeding on grain — where they can have easy access to it, and allow them to feed freely on it for several days. Then set the spring traps in these places, with the trigger very lightly caught.

Do not put anything under the "pan" of the trap; and do not put any bait inside the circle of the open jaws of the trap. Sprinkle food about the traps so that the rats will be likely to step on the pans when they pick it up. Cover the trap with chaff, bran, or earth and sprinkle a little oil of aniseed around the traps. Be sure that the trap is so fastened that the rat may drag it around a few feet. Do not set the traps in the same place twice in succession. These traps set in rat runways along building walls, ditch walls, or at the mouths of rat burrows, or on their trails to water will catch many a rat. In fact persistent use of traps will eventually rid a place of rats. But remember that it frequently requires not one but many traps, and more patience and shrewdness than the rats themselves have. Trapping mice is merely a matter of baiting and setting the traps, but trapping rats is a test of skill.

French cage traps can never be used with success without a period of baiting. Put freshly fried bacon, cheese, grain, or any other tempting bait into the trap every night for several nights and leave the back door of the trap open. When the rats have become bold about entering and eating, bait the trap as usual and close the back door. After you have made your catch, set the trap in another place and repeat the process.

Poisons are not safe for use in buildings or on city premises. Rats are too inconsiderate about choosing a place to die. Barium carbonate, mixed with egg and made into a paste with meal or breadcrumbs, is a cheap and effective poison. It is also about the safest poison because in small quantities it is not dangerous to domestic animals.

For fighting rats on farms, Farmers' Bulletin No. 896 offers a wide range of sound advice. See also Bulletin No. 33, Biological Survey, United States Department of Agriculture.

Project LVII. — *How to Read an Electric Meter and Compute the Cost of Current,* pages 486–487

In order to understand a few terms that are used in measuring electrical energy, let us liken the invisible electric current to a stream

of water. The electric stream may vary in size as does a stream of water. We speak of a stream of water as running so many gallons per second. The size of the electric current we measure in *amperes*. For example, only a small stream of one-half ampere is required to run an ordinary incandescent lamp of 16-candle power, but a large stream of five amperes is necessary to run an electric iron.

It is in connection with the size of the stream of electricity in a house that fuses serve the purpose of safety devices. For example, suppose your electric company has a 15-ampere fuse on your dining room circuit. Now suppose you are operating on this circuit two 16-candle power incandescent lamps, each requiring one-half ampere; and a toaster and a chafing-dish, each requiring 5 amperes. This makes a total of 11 amperes. If now you add a percolator, requiring 5 amperes, all the devices on the circuit together would demand a current of 16 amperes, and the overstrain would blow the 15-ampere fuse on that circuit.

The remedy is to put in a new 15-ampere fuse, and not to use so many devices on the circuit at the same time. Or it may be that the company will allow you a 20-ampere fuse on that circuit, so that you may use all the devices at the same time. *But do not use fuses of larger amperage without the consent of your electric company, because your wiring may not safely carry a larger stream.* If the fuse should be of larger amperage than the wiring would carry, an overload would burn out the wiring instead of the fuse. There must always be a safe margin between the size of stream your wiring will carry and the size of stream your fuses will withstand.

Water at the faucet is under a certain number of pounds of pressure (p. 201). This pressure has nothing to do with the size of the stream. For example, you may open the faucet only slightly and get a very small stream of water or you may open it wide and get a full stream. The pressure behind both streams is the same. What corresponds to pressure in a stream of electricity is measured in *volts*. The most common "pressure" or voltage for a lighting circuit is 110 to 120 volts.

The power of a stream of water flowing from a faucet depends on the size of the stream and the pressure behind it. The power

of an electric current depends on the size of the current (amperage), and the "pressure," or voltage. This power is measured in *watts*. The number of watts may be determined accurately for one kind of current and approximately for the other by simply multiplying the number of amperes by the number of volts. For example, an electric iron using a current of 5 amperes under pressure of 110 volts requires 550 watts of electrical energy to keep it heated. If this iron is used for an hour, we say that it consumes 550 *watt-hours* of current.

But a watt-hour indicates so small an amount of current that the commercial unit of measurement is the *kilowatt-hour*, 1000 watts for an hour's time. Another way of putting it is that 1 kilowatt-hour = 1000 watt-hours.

Your electric fixtures are marked with the number of amperes and volts necessary to run them. The iron mentioned above would

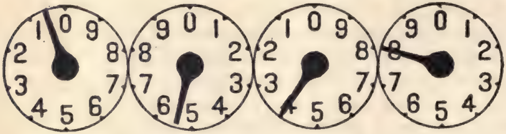


FIGURE 20. — DIAL OF A WATT-HOUR METER.

be marked "5 amperes, 110 volts." In an hour's time this would consume 550 watt-hours of current, as has been shown. This is $\frac{550}{1000}$, or .55, kilowatt-hour. If your company charges 10 ¢ a kilowatt-hour, it costs you .55×\$.10, or \$.055, to operate your electric iron for an hour.

An electric stove with all the switches open requires an electric stream of about 20 amperes. On a 110-volt current such a stove in full operation would consume in an hour 2200 watt-hours of current. This is $\frac{2200}{1000}$, or 2.2, kilowatt-hours. At 10 ¢ a kilowatt-hour, such an electric stove, with all the "burners" going, would cost 2.2×\$.10, or \$.22 an hour.

An incandescent lamp marked 40 watts indicates that it uses 40 watts of current per hour. A 40-watt incandescent lamp would therefore burn 25 hours ($1000 \div 40$) before it registered 1 kilowatt-hour, or 10 ¢ worth of current.

Reading the electric meter, or *watt-hour meter* (as it is called) is exactly the same as reading the water meter, except that the unit is kilowatt-hours, and the 100,000 circle is missing. Beginning at the right and reading to the left, the circles indicate units, tens, hundreds, thousands. The dial in Figure 20 reads 538 kilowatt-hours.

Notice that the hand in the tens circle is in a doubtful position. It must be read 30 because the hand in the unit circle has not yet reached 0. (See *Caution*, Project XXXII.)

PROJECT LVIII. — *How to Attach Wires to a Socket*, page 488

Caution. If you wish to attach a socket to the wiring of your house, be sure to open the switch at the fuse board, thus turning off the current from your house wires.

First remove the shell from the cap of the socket (A, Figure 21). If the shell is attached by screws or rivets, turn it to the left and pull it off. If the socket is old, the screws in the cap may have to be loosened. If the shell has a corrugated upper edge that springs into the cap, it may be removed by pressing it firmly near the key (the place is indicated on most shells by the word "Press") and pulling it out of the cap.

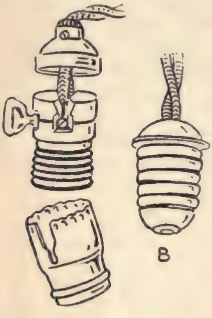
Notice that the cap and shell are completely lined with insulating material. If the insulating material is missing or damaged, do not use the socket; it is dangerous.

Cut off the ends of the two wires even. Remove the insulation from the ends of the wires just far enough back to allow bare wire ends to fit under the attachment screws of the core (A, Figure 21). To do this, cut through the braided cover and scrape off the insulation around the wires. In removing this insulation, be very careful not to cut the filaments of wire within.

When the insulation is removed, roll the exposed filaments of

wire between your thumb and forefinger into a compact strand that will fit snugly under the screws of the core.

Slip the cap over the two wires, as in A, Figure 21. Loosen the attachment screws on the core, bend a wire end around each of the two screws in clockwise direction, and tighten the screws again.



B

A

FIGURE 21.

Replace the shell. If it is attached to the cap by screws, slip the screws into the grooves and turn the shell to the right. If it is the spring type of shell, push the upper edge of it into the cap until you hear it click.

If you succeed in taking a socket apart and wiring it, you will have no difficulty in taking almost any sort of plug apart and attaching wires to it. Just be careful to put the parts back in the order in which you removed them. Figure 21, B, shows one type of attachment plug.

Two of the most interesting and practical books on electricity for beginners are:

"The American Boys' Book of Electricity," Charles H. Seaver. David McKay.

"Harpers' Electricity Book for Boys," Joseph H. Adams. Harper & Bros.

PROJECT LIX. — *How to Make the Acquaintance of Trees and Wild Flowers* (Independent Project)

Projects LIX and LX are independent projects, not specifically connected with any particular portion of the text of this book. But in a larger sense, they are very vitally related to the entire book. One of the chief purposes of *Everyday Science* is to encourage an interest in the great out-of-doors. No one can

spend much time out of doors without having a desire to become better acquainted with the birds, trees, and undergrowth. Unfortunately, wild forest life is so scarce in most thickly settled regions, that few boys and girls have the opportunity to make a study of it.

Guidance for the study of outdoor life cannot be given except in books devoted wholly to that purpose. As a general guide for beginners in the study of the out-of-doors, probably no book excels the "Official Handbook of the Boy Scouts of America" (200 Fifth Avenue, New York). "The Book of Woodcraft," by Ernest Thompson Seton (Doubleday, Page & Co.) is another book in which boys and girls devoted to outdoor life can find a mine of interesting and valuable information.

Among the best guides to the study of trees and wild flowers are the following books:

"Field Book of American Trees and Shrubs," F. Schuyler Mathews. G. P. Putnam's Sons. No other one book is as satisfactory as this for the identification of trees and shrubs.

"Studies of Trees," J. J. Levison. John Wiley and Sons. This is probably the most satisfactory all-around book for beginners on the identification of common trees, choice of shade trees, care of trees, and elementary forestry.

"The Tree Guide," Julia Ellen Rogers. Doubleday, Page & Co. A convenient pocket-size guide that enables the forest rambler to identify trees by their foliage.

"The Forester's Manual," Ernest Thompson Seton. Doubleday, Page & Co. A guide to the trees of Eastern North America, with maps showing the distribution of each tree described.

"The Trees of California," Willis Linn Jepson. Cunningham, Curtiss and Welch, San Francisco.

"Field Book of American Wild Flowers," F. Schuyler Mathews. G. P. Putnam's Sons. This is the most satisfactory handbook for the identification of wild flowers. Its abundance of illustrations makes it particularly useful to the beginner or amateur.

"Wild Flowers Every Child Should Know," Frederic William Stack. Doubleday, Page & Co. A valuable feature of this book

for the beginner is its arrangement of the most common wild flowers according to color.

"Wild Flowers of the North American Mountains," Julia W. Henshaw. Robert M. McBride Co. This is a beautiful guide to the flowers of the Rockies.

"Field Book of Western Wild Flowers," Margaret Armstrong. G. P. Putnam's Sons. A very satisfactory guide to the wild flowers of the regions west of the Rockies.

"Flower Guide," Chester A. Reed. Doubleday, Page & Co. A pocket-size guide illustrated in color for the forest rambler.

PROJECT LX. — *How to Study Bird Life* (Independent Project)

Three bulletins of the United States Department of Agriculture make a very good introduction to the study of the common birds:

"Fifty Common Birds," Farmers' Bulletin No. 513 (15 ¢).

"Bird Houses and How to Build Them," Farmers' Bulletin No. 609.

"The English Sparrow as a Pest," Farmers' Bulletin No. 493.

Among the most reliable and usable manuals for the identification of North American birds are the following:

"What Bird Is That?" Frank M. Chapman. D. Appleton & Co., 1920. This is the most usable handbook of birds for the United States east of the Rocky Mountains. Every land bird in that section is pictured in color. The color plates group the birds according to season, and indicate the relative sizes of birds. The accompanying text is simple but thoroughly adequate. This is not an expensive book.

"Color Key to North American Birds," Frank M. Chapman. D. Appleton & Co., 1912. The title indicates the character of this book. It is a guide to bird study throughout the North American continent.

"Birds of the Rockies," Leander S. Keyser. A. C. McClurg & Co.

"Birds of California," Irene Grosvenor Wheelock. A. C. McClurg & Co.

"Handbook of Birds of the Western United States," Florence M. Bailey. Houghton Mifflin Co., 1917. This is a complete guide for the great plains, the great basin, the Pacific slope, and the lower Rio Grande valley.

Among the most interesting books about birds are the following:

"Bird Friends," Gilbert H. Trafton. Houghton Mifflin Co., 1916. This treats of the life of birds, their economic value, the enemies of birds, the protection of birds, and methods of attracting them.

"Wild Bird Guests; How to Entertain Them," E. H. Baynes. E. P. Dutton & Co., 1915.

"Homing with the Birds," Gene Stratton-Porter. Doubleday, Page & Co., 1919.

"Methods of Attracting Birds," Gilbert H. Trafton. Houghton Mifflin Co., 1910.

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